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Physics is Physics[1]

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PERHAPS I can best elucidate the rather cryptic title of this paper by quoting a remark of the late Professor G. W. Jones, Professor of Mathematics at Cornell University from 1877 to 1907 and one of the best teachers who ever occupied a professorial chair. It is told that an embryo teacher, taking one of Professor Jones' courses, once asked him: "What must one do to become a successful teacher of mathematics?"; to which Jones replied: "To become a successful teacher of mathematics one must acquire a thorough knowledge of mathematics."

I am sure that every member of Section Q, and probably many educationists, would agree with Professor Jones' statement, *as far as it goes.* I am equally sure that these same persons would agree at once with the converse statement that no person can become a successful teacher of any subject unless he possesses an adequate knowledge of that subject, even though that person may have had all of the courses in education given in one of the larger universities—79 of them at Cornell! May I point out, however, parenthetically, that the impression seems to be rather prevalent that there is another group of persons, composed mainly of certain other educationists and educational administrators, which takes issue with this second statement and which, to judge from the ever increasing number of semester-hours of education required of prospective public school teachers, holds the view that training in teaching methods is both "*necessary and sufficient*" to make competent teachers. With the views of this latter group I am not particularly concerned in this paper. Rather, I wish to discuss an obvious extension of Professor Jones' statement, an extension which he himself without doubt had in mind, as one would infer from his extraordinary success as a teacher.

That a knowledge of subject matter, however thorough that knowledge may be, is not of itself an *entirely* adequate preparation for teaching is at once recognized from the fact that there are many excellent scholars who are poor teachers. (I hasten to add, however, that many such scholars who are seeming failures as teachers of the more elementary branches of a subject are most inspiring teachers of the more advanced courses.) Something else than a knowledge of the subject is necessary. That something is, I believe, the acquisition of the *art* of teaching. And it is primarily to this last statement that I wish to direct my remarks.

Teaching, I say, is an art, and not a science. In a recent address before Science Service[2] Dr. Robert A. Millikan characterized a science as comprising first of all "a body of factual knowledge accepted as correct by all workers in the field." Surrounding this body of knowledge is a fringe, narrow or wide as the case may be, which represents the controversial part of the science. And outside of this fringe is the great unknown.

[1] A paper presented before Section Q (Education) of the American Association for the Advancement of Science at the Atlantic City Meeting, December 28, 1932.

[2] See The Scientific Monthly **35**, 203 (1932).

Investigators are constantly exploring this controversial region; making hypotheses and theories; devising experiments to test those theories; and gradually enlarging the boundaries of accepted facts. Without a reasonable foundation of accepted fact, no subject can lay claim to the appellation "science."

If this definition of a science be accepted—and it seems to me very sound—then I believe that one must admit that in no sense can teaching be said to be a science. Probably every one would agree with this statement and perhaps it is therefore unnecessary to make it, except as a starting point for the discussion. But to make perfectly clear what I mean, let us consider an illustration.

If one were to select the ten best teachers of sophomore college physics in America and were to ask each one to write his statement of Ohm's law, one would find that the ten statements would be substantially identical except for differences in phraseology; for, Ohm's law forms part of the factual content of physics and is accepted as correct by all physicists. But if one were to ask those same teachers for a statement of the methods used by each in presenting Ohm's law to his classes, one would probably receive ten quite different answers. Each teacher uses his own methods of presentation, developed by him as best suited to his own personal traits and peculiarities, to the type of student whom he is at the moment teaching, and to the institution in which he is teaching. He has acquired his particular technique by the trial-and-error method, analyzing as objectively as he can his own reactions to the various methods which he has tried; studying the methods used by other successful teachers; and usually varying his procedure from class to class and from year to year so that he shall never become a mere machine. Though each of the ten men may be a highly successful teacher one searches in vain for any accepted body of factual knowledge upon which his success as a teacher is built. Nowhere do we find a basis for a scientific analysis of the methods which these men use. Rather, insofar as he is a teacher, each of the ten is an artist, with an artist's viewpoint toward, and an artist's pride in, his work.

The scientist pursues his work objectively. But is it characteristic of the artist that *his* work reflects his own personality. If he merely copies the work of another, he is no real artist. Certainly, there is no profession which has greater potentialities for reflecting personality than that of teaching. I repeat, then, that teaching is an art. If this statement be accepted as correct, we have taken an important step in any attempt to delineate the training which a teacher should have —in addition of course to his acquisition of subject matter—for in preparation for his *teaching* he should be trained in some respects as an artist is trained, and not as a scientist.

Now, the type of training given an artist differs widely from that given the scientist or the engineer. A student of civil engineering will study bridge design and construction; he will learn about moments of inertia of cross section, and about tensile strengths of materials; about cantilever construction and suspended arches; he will study the design and erection of great bridges—all this objectively. He will become familiar with the great body of knowledge accepted as basic in bridge engineering. And then he is prepared to undertake his professional work.

An artist on the contrary, say a violinist, acquires his training in quite a different way. He begins by actually playing the violin—as fathers and mothers are sometimes painfully aware! And as he plays he acquires skill, partly by virtue of increased experience, partly by the guiding comments and help of teachers who themselves are usually skilled violinists. He studies the works of great composers and the performances of great artists; not that he may imitate such performances, but that he may, by observing them, the better build a foundation for his own art.

It is important to note that there *is* a considerable body of scientific knowledge underlying music. For example, the frequency of vibration of a violin string of given length and mass per unit length is proportional to the square root of the tension. Therefore, in tuning the string a change of one percent in tension results in a change of two percent in pitch. If the violinist wishes to sound middle C on his G string he has to decrease its length exactly 25 percent. His open E string has a very strong fundamental and a prominent second overtone; the fundamental of the open G string is relatively weak while the third overtone is strong. The average violinist, however, is no more interested in these funda-

mental scientific facts regarding the performance of his instrument than are the members of Section Q. He tunes his instrument and produces various tones and tone effects not according to formula, but "by ear." He would *perhaps* be regarded as a more cultured violinist if he *could* derive the formula for the frequency of a vibrating string; but his art as a violinist would not be improved by that accomplishment. In short, there is a very fundamental science underlying music, a science which it is very important to cultivate; but may I point out that the musician does not begin his education by studying that science.

Now, of course, I agree at once that one cannot carry the similarity between the training of an artist and the training of the teacher too far. There are very fundamental points of difference. For example, it is imperative, as I pointed out at the beginning, that the teacher shall first acquire a thorough knowledge of his subject—a knowledge which extends much beyond those parts of his subject which he is initially to teach. The musician faces no such preliminary requirement. The early efforts of the teacher cannot be as closely observed and directed as can those of the artist. The teacher, say, of science, must remember that though as a *teacher* he may be an artist, he is at the same time a *scientist.* He must approach the subject matter in his field *always* in the latter capacity. Without that approach he can never be a successful teacher. But he must approach the *presentation* of that subject matter to his students as an artist; without *that* approach he can scarcely become a successful teacher. The relation of teacher to students is, in general, much more intimate than that of the artist to his audience. And finally, I admit without argument, though with some reservations, that a part of the curricular subject matter generally referred to as "Education" is somewhat more closely connected with teaching than is the science underlying music, with music.

Nevertheless, there are certain aspects of the training of an artist which it is desirable to have in mind in our thinking on the subject of teacher training. For example, the music teacher periodically observes the playing of the embryo violinist, gives him frequent criticism and suggestion, and urges him constantly to study and to try to improve upon his own performance. Not so with the young teacher.

Probably the majority of college and university teachers get their first teaching experience by acting as teaching fellows or assistants during the period of graduate study. Since, on the one hand, the primary purpose of our graduate school is, *and always should be,* to offer to capable young men and women opportunities for advanced study and research, to the end that the spirit of productive scholarship shall continue to motivate our faculties of the future; and since, on the other hand, the student realizes that his graduate work is the *sine-qua-non* of that much-coveted doctorate, it is perhaps but natural that both student and professor should think of the former's teaching as merely a means of support during graduate study, which study is his main business. The result is that very frequently the young teacher, unlike the young artist, is left largely to his own resources so far as his teaching is concerned. He has begun his work with very little, if any, previous study of the problems of teaching. He seldom receives preliminary "coaching" from experienced teachers. The urge to analyze subjectively his own methods and performance as a teacher is usually lacking. As a teacher he "grows up like Topsy," not realizing, because no one has told him, that in preparation for his future career as a member of a college faculty, this opportunity to acquire teaching experience is second only to the opportunity to do graduate work. I believe that this situation is unfortunate, and should be remedied. But how?

There are those who urge that the graduate student should not be allowed to teach; that it is "hard on the undergraduate students" whom he teaches; that during graduate work he should, if he wishes to enter the teaching profession, prepare himself therefor by taking the various courses offered by the Department or School of Education. With these several views I partially disagree. Usually, the young teacher is selected and appointed on the basis of his potential teaching ability, as judged from his work as a student. *If the selection has been wisely made,* the young man will usually make up for any shortcomings in his classroom technique by a fresh and infectious enthusiasm for the subject taught. He is still close enough to his own difficulties as a

student to be able to appreciate sympathetically those of the students under him. Somehow, he "muddles through" in spite of lack of guidance. The harm is not so much to his students. Rather it is to himself, for he has failed to make *best* use of the opportunity to acquire experience at a particularly important period in his development. Nevertheless, I have very frequently observed that those who develop into good teachers are good teachers almost from the start.

Further, I believe that the young teacher must acquire *his* art of teaching by actual teaching—not by studying in advance "how to teach," nor by play-teaching. Let me not be misunderstood. I regard the subject of education as a very important part of the curriculum, on a par with history, philosophy, chemistry or geology, and equally worthy of study and research. I would urge that it is just as important to offer students, whether they expect to become teachers or not, an opportunity to become acquainted with the history of education and with modern educational systems in this country and elsewhere, as it is to offer courses in the history of political institutions and in modern forms of government. Indeed I would even urge that, in parallel with his teaching, the graduate student who expects to become a teacher should take *suitable* courses in the principles and methods of education—if such courses be available!—not at all that he might find the subject matter of those courses directly applicable to his teaching in the same way that a course in bridge construction helps the bridge engineer—but rather that he might find in those courses yet one more inspiration to perfect his own art.

The responsibility, then, for training young teachers lies, I believe, with the subject-matter departments. It is the duty of the older, more experienced teachers in a department to impress the idea upon the beginner, by precept, example, and friendly counsel, that teaching is a serious business, requiring careful study; that his obligations to his students, present and future, require that he should make every effort to profit by the opportunity to acquire teaching experience under guidance; and that to this end he should strive to adopt teaching methods best suited to his own personal characteristics, to his students and to the subject matter taught. Indeed, the Committee on College and University Teaching of the American Association of University Professors recommends that, so far as may be possible, every college or university department should have on its staff at least one professor fitted by both aptitude and experience to advise with beginning teachers concerning their teaching problems. It is hardly necessary to point out that such advice cannot effectively be given by one officer for the university as a whole. For, the problems which the teacher of chemistry will encounter differ markedly from those encountered by the teacher of English; and further, it is almost imperative that the adviser should be more or less intimately acquainted with the young teacher's personal peculiarities and traits. In short, physics is physics; history is history; education is education. And there is not much to be gained by mixing them, so far as methods of teaching are concerned. Teaching, like charity, begins at home.

Granted, however, that the young teacher must develop his own art with such inspiration and help as he can get from his older colleagues and otherwise, should we not place before him a statement of what constitutes good teaching to serve as a standard of comparison for his guidance? I have seen many attempts to prepare such a statement, but I know of only one which is not open to criticism of the most serious kind: "Good teaching is the kind of teaching done by a good teacher."

I have in mind two teachers, neither now active. The one, a teacher of physics, was, as a teacher, an outstanding artist as I have used that term. He constantly studied his classroom and lecture technique. His methods and results would have justly merited the applause of the most critical educationist. He was recognized by both students and colleagues as a most successful and inspiring teacher.

The other was a teacher of engineering. To judge from the haphazard manner in which his teaching was done, he should have been a dismal failure as a teacher. But if one judges him, not by his classroom performance nor by grades received by his students in his courses, but by the only yardstick which is really trustworthy, namely, the extent to which his teaching influenced his students in their professional work

after Commencement day, he must be regarded as one of the most successful teachers in America. He imparted not so much information as inspiration. His teaching simply reflected his own enthusiasm for the branch of engineering which he taught and in which he had made for himself an international reputation. I suspect that his teaching would have been colorless and ineffective, had he been required to use the more conventional classroom methods.

Dean Fernandus Payne in a report prepared for the Committee on College and University Teaching, above mentioned, describes the ideal teacher as follows: "If I were selecting a teacher I should look for a person of broad scholarly training, interest and culture; one who was interested in teaching; and one who could look upon the problems of the student with sympathy and understanding. This ideal teacher should have the energy and the enthusiasm which should accompany an inspiring and stimulating personality. I should look for a person who was logical in thought, thorough in preparation, and who was willing to work at the job. I should expect initiative, originality, adaptability, aggressiveness, and perhaps it would not be too much to expect a certain degree of refinement. Most certainly I should not avoid the man who was intensely interested in research." And Dean Payne adds: ". . . Such a prescription would be difficult to fill. . . . If you knew such a person there would be a wild scramble to get him. . . . In a generation, only a few such (ideal) individuals are found." The Mark Hopkins and the Agassizs are as rare as the Paganinis and the Kreislers.

It is frequently remarked that we American teachers teach far too much in comparison with our European colleagues; that it is better for the student if we expect him to take *some* initiative in his reading, studying and thinking. This criticism of the American method is, I believe, justified; but I do not think that the criticism applies to our *training* of college teachers. I do not think that we train them too much! Perhaps we overdo the matter of leaving them so much to their own devices. But even so, I believe that our present system is by no means a failure, though it is subject to improvement, we all admit. I believe that college and university teaching, by and large, is well done; that we have on our college faculties a large number of very capable, enthusiastic teachers. Only, we must be very careful to select the correct yardstick to measure success.

I believe that improvements may best be made by expecting the subject matter departments to take much greater responsibility for teacher training than they have in the past. I believe that we should make much more of an effort to seek out from among our students, both graduate and undergraduate, those who give promise of becoming good teachers, as well as those who give promise of becoming good scholars, and encourage the former to enter the teaching profession. Such selection can be made only by the members of the subject matter departments. Again I repeat: "Physics is physics." And if we leave the selection and training of physics teachers to the physicists, and place upon them the responsibility for doing a good job, we need never fear, I fancy, that subject-matter requirements will be neglected.

We may now complete Professor Jones' statement with which I began: "To become a successful teacher of mathematics one must acquire a thorough knowledge of mathematics, and then by constant practice, acquire the art of teaching it."

The Usefulness of Objective Physics Tests of the Reasoning Type[1]

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MY introduction to objective tests occurred shortly after my coming to the University of Pittsburgh. My colleague, Dr. O. H. Blackwood, officiated. He was in charge of college physics and, when the time came to consider the first six-weeks test, he broached the idea of a test of the objective type. I glibly agreed that I was willing to try most anything once, and we set to work preparing questions. As I recall it, a test with about twenty objectives resulted. I think we must have had some misgivings, for it was decided first to try out the test on the group of nine graduate assistants who were then on the teaching staff. The results were astonishing. As is quite common with such tests, penalties were inflicted for wrong answers. I remember well that the grades were scattered altogether too regularly from a plus 90 down to a negative 10 or 20. Not more than three or four obtained a fair rating. To eight of the nine, master's degrees have since been given; and one of these eight will soon be given a doctor's degree. Of those who were given master's degrees, we definitely decided that three could not hope for a further degree, and that four could expect to take a doctor's degree with profit. While I no longer have the exact records, I do recall that three of the four, whom we later considered to be of Ph.D. caliber, stood at the head of the list, and that two of those to whom we would not give a doctor's degree stood at the bottom of the list. It almost seems as though we could have foretold from that simple examination of twenty objectives planned for students taking college physics, the probable futures of those assistants so far as work in physics was concerned.[2] I have completely forgotten how the undergraduate students, for whom the test was intended, responded to it. Its influence, however, has been far reaching for both undergraduates and graduates at the University of Pittsburgh.

Since that early test, many others of a similar nature have been given. A more or less standardized type of question has been arrived at as most suitable. It is the multiple-choice type, that one in which the student is supplied with several answers to a question including, of course, the correct one, and is asked to make his choice. Let us now consider how we make use of them, first in connection with our undergraduate introductory course and then in connection with our grading tests for M.S. and Ph.D. candidates.

In our introductory college physics course, we regularly give examinations which are partly of the objective and partly of the problem or classical type. The objective portion of such a recent examination is shown in Table I. As may be seen, 40 credits out of a possible 100 might be gained from this part. Further, no penalties were given for incorrect answers. Just how one should classify some of the questions naturally depends upon whether or not consideration has been given to the same or similar material in previous classwork and, if given, to what extent given. With this understanding, we can say with some certainty that the students for whom this test was devised found questions 1, 3, 6, 8 and possibly also 7, to demand the use of reason. On the other hand, numbers 2, 4, 5, and possibly 7 might be classed, in part at least, as memory questions. Other students to whom this same test might conceivably be given, would undoubtedly classify the questions differently.

Born of experience, it is our feeling at the University of Pittsburgh that we must include in our tests questions of the memory type in order to offer something of comfort to those students who are more or less devoid of the power of imagining a physical situation and of applying reason

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[1] Read before the American Association of Physics Teachers at the Atlantic City meeting, December 30, 1932.

[2] The records have since been found. The case is even stronger than as presented. One graduate assistant who had an M.S. should have been included in the list. Of the four receiving the lowest grades, one left at the close of the school year. The other three were the only ones who were later told that they could hope for no degree beyond the M.S.

TABLE I. *Specimen examination in general physics including objective questions of the reasoning type.*

University of Pittsburgh Physics 1 b October 26, 1932

NAME .... INSTRUCTOR ....

Part I. Objectives. Answer all. Credit 5 each.

1. .... Two objects, A and B, when tied together, weigh 10 g in water. A alone weighs 25 g in water. The specific gravity of B is (a) equal to, (b) greater than, (c) less than, that of A.
2. .... The equation $v=u+at$ applies to motion in which (a) the velocity is constant, (b) the speed is constant, (c) the acceleration is constant, (d) the acceleration increases uniformly with time.
[3]3. .... The torque which a man can apply to a screw, using a screw-driver with a thick handle, is (a) greater than, (b) equal to, (c) less than, that which he can apply with another screw-driver which has a thinner handle.
4. .... The magnitude of the resultant of two equal forces is (a) always, (b) sometimes, (c) never, less than the magnitude of either of them.
5. .... In a vessel, shaped as shown, containing water, A and B are two points on the same horizontal level. The pressure at A is (a) greater than, (b) equal to, (c) less than, that at B. See Fig. 1.

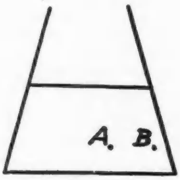

FIG. 1.

6. .... If the U. S. dirigible Akron just floats in the air at a certain place, neither rising nor falling, the density of the gas inside its envelope is (a) greater than, (b) equal to, (c) less than, that of the surrounding air.
7. .... An object, starting from rest, falls freely toward the ground. The change in its velocity during the first second is (a) greater than, (b) equal to, (c) less than, the corresponding change during the fourth second of its fall. Neglect air resistance.
8. .... As an air bubble rises from the bottom of a lake toward the surface, the buoyant force on it (a) increases, (b) decreases, (c) does not change.

Part II. Answer 4 questions. Credit 15 each.

9. A short heavy metal cylinder (see Fig. 2) is lowered,

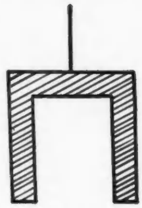

FIG. 2.

open end downwards, to a depth of 30.6 meters in fresh water. If the barometric pressure is 75 cm of mercury, (a) what will be the pressure of the air trapped in the cylinder; (b) what fraction of the cylinder will be filled with water?
10. A uniform beam 12 ft. long and weighing 80 lbs. is supported at two points 2 ft. from each end. A load of 60 lbs. is on one end of the beam, and 100 lbs. on the other. Find the force on each support.
11. A metal ball weighs 54.6 g in air and 48.1 g in water. (a) Compute its specific gravity. (b) What will it weigh in a liquid of specific gravity of 0.80?
12. A heavy object is thrown horizontally, with a velocity of 50 ft./sec., from the edge of the roof of a building 128 ft. high. (a) How soon will it strike the ground? (b) How far from the building will it strike the ground?
13. A 300-lb. weight is supported by a 20-ft. cable. What is the maximum distance this weight can be pulled sideways by a man who exerts a pull of 100 lbs. on a rope attached to the lower end of the cable? Show in a diagram the direction of the pull.
14. Two trains A and B on parallel tracks are side by side and moving in the same direction with a speed of 30 mi./hr. Train A continues at constant speed. Train B comes to rest with a uniform deceleration in 330 ft., waits two minutes, and then with constant acceleration regains its original speed in another 330 ft. How far will train B then be behind train A?

to its solution. Generally, questions of the reasoning type are productive of high mortalities. I regret that, in the case of this particular test, I have no information as to just how great that mortality was in comparison with that for questions of the memory type.

Occasionally, a student complains about the interpretation given to an objective question, and we have learned, as instructors, to take great care to state a question in such manner that there can be no reasonable cause for misunderstanding, that there is but one definite answer and that this answer is included as one of the possible choices.

[3] It might have been desirable to specify that equally firm grips were to be assumed for the two cases.—Author.

To illustrate, such an objective as, "The potential energy which a body possesses in a certain position (a) is, (b) is not, the work that has been done in taking the body to that position," is faulty in two respects at least. First, as stated it is uncertain whether the potential energy referred to is that which the body possesses because of its position with respect to the earth's surface or something else; second, it is uncertain whether the work that has been done, has been done in part to overcome friction or not. The question is better by far when stated as follows: "The potential energy which a body in a certain position possesses with respect to the earth's surface (a) is, (b) is not, equal to the work that must be

TABLE II. *Two arbitrarily selected groups of questions from the 100-question, 3-hour test for M.S. candidates.*

Place in the space left at the upper left corner of each question the letter which makes the statement correct.

The credit for a correct answer is 1, the penalty for an incorrect answer is −1. If you are uncertain but wish to hazard a guess, do so by writing a capital G at the left before the letter indicating your choice. In that case, the credit will be ½, and there will be no penalty.

It will be to your advantage to go first through the list answering those you can answer quickly and then to do the remainder, giving those that are more difficult the time that you can spare.

1. .... At a height of 2 miles above sea level the atmospheric pressure is closely ⅔ of what it is at sea level. At a height of 4 miles the atmospheric pressure (a) is more than, (b) is about equal to, (c) is less than, ⅓ that at sea level.
2. .... An acceleration of 10 cm/sec.×min. is (a) greater than, (b) equal to, (c) less than, 10 cm/min.×sec.
3. .... The kinetic energy due to rotation which a marble rolling on a floor possesses is (a) greater than, (b) equal to, (c) less than, that which it possesses on account of its translation.
4. .... The volume modulus of elasticity of water is (a) greater than, (b) less than, that of ordinary rubber.
5. .... In glass capillary tubes, water is drawn upward and mercury is depressed. This (a) means, (b) does not mean, that mercury does not possess a surface tension.
6. .... The force required to drag a sack of cement across a floor at a speed of 2 ft./sec. is (a) noticeably greater than, (b) approximately equal to, (c) noticeably less than, that required at a speed of 1 ft./sec.
7. .... A ring and a solid rod of the same diameter roll down a slope together. The speed of the ring at the bottom is (a) greater than, (b) equal to, (c) less than, that of the rod.
8. .... Disregarding friction, it requires (a) more, (b) the same, (c) less, ***work*** to change the speed of a body from 10 cm/sec. to 15 cm/sec. than to change from 15 cm/sec. to 20 cm/sec.

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85. .... The illumination of a certain surface is 10 foot-candles. This means that it is receiving per unit area (a) twice, (b) four times, (c) eight times, as much light as a surface whose illumination is 5 footcandles.
86. .... Lamp A is 6 ft. above a surface and produces at the surface twice the illumination that is produced by lamp B, which is 10 ft. above the surface. It is (a) not possible, (b) possible by raising the surface, (c) possible by lowering the surface, to find a position where the separate illuminations are equal.
87. .... In two plane mirrors forming an angle of 72° with each other, there may be seen just (a) two, (b) three, (c) four, (d) five, images of an object placed in the space between them.
88. .... A difference of 5 in the magnitude of stars indicates an illumination ratio of 100. The stellar magnitude of the sun is −26.7, of the full moon −12.5. This means that the illumination produced at the earth's surface by the sun is roughly (a) 280 times, (b) 500,000 times, that produced by the full moon.
89. .... The moon's diameter is about 0.3 of that of the earth. Assuming that the earth reflects about the same percentage of the incident sunlight that the moon does, the illumination due to a full moon at the earth is (a) 0.3, (b) 0.09, (c) 0.027, (d) 0.0081, that due to a "full earth" at the moon.
90. .... If an object is placed between the principal focus and center of curvature of a concave mirror, the image appears (a) between the mirror and the principal focus, (b) outside the radius of curvature, (c) between the principal focus and radius of curvature.
91. .... The image of a large cube placed between the center of curvature and the principal focus of a concave mirror (a) is, (b) is not, another cube.
92. .... A convex spectacle lens moved up and down in front of the eye will cause distant objects to apparently move up and down (a) in unison, (b) in reversed order.

done on the body, disregarding friction, in taking it from the surface of the earth to that position." Although beyond most students who would take such a test, the refinement is not beyond all, particularly those who are most able. It takes much longer to formulate satisfactory objective questions than questions of the older or classical type. It is the feeling of the instructors who make out these tests that the objective portion yields at least as definite criterions as to student ability as does the remainder or classical portion.

As in most institutions where graduate work is carried on, we give early preliminary examinations to graduate students who are candidates for the M.S. and the Ph.D. degrees, in order to determine their status as students. At first, the various members of our major staff "sat in" on oral examinations given individually to the candidates. These oral examinations were excellent in that they yielded conclusive evidence as to the abilities of the candidates; however, they were quite time-consuming and tended toward too restricted surveys in the various fields. Moreover, the candidates themselves sometimes gained opinions as to their accomplishments which differed greatly from those held by their inquisitors. Always in such cases the candidates have held exalted ideas regarding their performances. With the hope, in part, to overcome these objections and in part to secure a standard which should be pretty much the same from year to year, it was decided to give the candidates as they appeared a common objective test. Taking advantage of an enforced vacation while recuperating from scarlet fever, the writer reviewed all the objective questions which had been given in the preceding five years in connection with our introductory course in college physics, and selected therefrom many objectives which, together with a few others, were built into a 100-question, 3-hour test in general

physics for M.S. candidates. As samples, two arbitrarily selected groups of questions are shown in Table II. As is indicated in the heading, in the scoring, a penalty is given for an incorrect answer. Of these questions, those numbered 1, 3, 6, 7, 86, 87, 88, 89, 91, 92 are considered to be of the reasoning type; whereas the others though somewhat of the same nature are certainly less so. That these questions generally demand the use of reason rather than memory for their answer is the general impression of the students who have taken this test and, I think, also of those teachers of physics who have looked over the test.

A summary showing grades, question by question, for part of the fifty-five sets of answers which have been obtained from this test, is shown in Table III. It may be readily seen that the questions which have been indicated as of the reasoning type are particularly productive of negative and zero grades. That the physics which many of these candidates possessed was "memory physics" seems to be the unfortunate conclusion.

TABLE III. *Summary showing grades obtained on the questions reported in Table II, as shown on every third set of answers when arranged in order of excellence.*

	Questions																*100 Questions*		
Student	1	2	3	4	5	6	7	8	85	86	87	88	89	90	91	92	Score	No. of guesses	Correct answers
1																	97	1	98
4								–									86	1	91
7							–					0				0	80	0	87
10										–	–						76½	5	88
13																	69	5	83
16		–	0				–		0								67	5	82
19				0		–	–			–	–						62½	6	79
22	–						½	–		–	½	½	0	½	0		57½	14	78
25	–		–				0	–		–	0			0			53½	16	74
28	–						–				0	–	½	–	–		52½	7	74
31	½	–	–				½		–	–	0	0					48½	17	73
34	–						0	–			0					0	47	0	71
37	–			–			–			–	–	0	½		–	–	45½	8	71
40	–						–	–			–	–				½	42	10	70
43	0		–				–	–							½	–	38	21	63
46	–					–	0			–	0	–	–			0	35	0	62
49	–		0	–			–	–		–	½	0		½	½	0	28½	26	60
52	–	–					–	–		–	–	–				–	13	9	55
55	–	–	–					–	–	0	0		0	–		½	–12	5	42

The symbol (–) indicates an incorrect answer, (0) an incorrect guess or no attempt to answer, (½) a correct guess. Correct answers are indicated by clear spaces.

At the right are shown the scores obtained, the number of guesses made, and the number of correct answers.

We had looked to these tests for indications of lack of preparation in certain fields, also strength in other fields. The results, however, generally show that whenever a student has been weak in one field, he has been weak throughout, and when a student has been strong in one field, he has been strong throughout. Some exceptions to this are found. One otherwise strong student was predominantly weak in Light at the time of the test; another strong one was weak in a portion of the Heat field.

It has generally been agreed by the students that the test has been severe and that, through surveying a large field, it has been fair. In only two cases that I recall as I write this, have any of these graduate students complained that the results did not give a fair indication of what they knew about physics. Those two, incidentally, had the lowest grades of all, except for one.

Students have, at all times, been given an opportunity to discuss their papers with a major staff member, and those discussions based naturally on the answers given in the tests have often been quite illuminating as to the student's understanding either creditably or otherwise of what constitutes physics.

Incidentally, this test for M.S. candidates has been used at different times in connection with a course entitled, "Basic Concepts in Physics." In such cases, those whose scores fell below a minimum of 45 but still not too low were given incomplete grades for the course with the understanding that if they should make up a similar list of questions of suitable quality, with answers, this deficiency would be removed. Of the several who have been given this choice, three have found it possible to make out suitable lists of questions, each one agreeing that in the process he had gained about as much as he had while taking the course originally.

Turning now to the Ph.D. preliminary, its purpose obviously is that of discovering those who are capable and are to be encouraged to go on in physics and also those who should be encouraged at once to seek positions elsewhere wherein they can serve. Initially, our objective tests for these students consisted of some multiple-choice and some completion questions. I think, were we to make out a new set, we should be inclined to make them all of the multiple-choice type. The questions for the Ph.D. candidates that are found satisfactory are much of the same type as those given to master's candidates, differing in being somewhat more difficult. In Table IV are shown sample questions from our 100-question, 3-hour,

Ph.D. preliminary test. The reader may feel inclined, on looking it over, to conclude that the questions are not difficult, and undoubtedly such is the case; but we have yet to find the candidate who, taking the questions all in all, has not found them sufficiently so. Thus far, no one has obtained a score appreciably in excess of 80.

TABLE IV. *Sample questions for Ph.D. preliminary.*

1. .... A force may (a) always, (b) sometimes, (c) never, be replaced by another force and a couple.
2. .... A block slides and a cylinder rolls, both from rest and without appreciable losses due to friction, down the same incline. The velocity of the cylinder at the bottom is (a) greater than, (b) less than, (c) the same as, that of the block.
3. .... The work done in adiabatically compressing a gas initially in a given condition to one-half its original volume is (a) greater than, (b) equal to, (c) less than, that done when the compression is isothermal.
4. .... The coefficients of volume expansion at room temperature for pure metals having low melting points are usually (a) greater than, (b) less than, (c) about the same as, those for metals having high melting points.
5. .... An incandescent black body made of carbon is (a) brighter than, (b) as bright as, (c) not so bright as, one of tungsten at the same temperature.
6. .... When a perfect gas expands freely into an evacuated space, its entropy (a) increases, (b) decreases, (c) remains unchanged.
7. .... The surface tension of alcohol is about one-third that of water. Ripples having a wave-length of ½ mm will travel in alcohol with a speed that is (a) greater than, (b) the same as, (c) less than, that for ripples of the same wave-length in water.
8. .... To bring a diamagnetic body up to a magnetic pole (a) requires, (b) does not require, the performance of work by an external agent.
9. .... A copper rod is partially immersed in an electrolyte of $CuSO_4$ through which no current flows. The electrical potential of the portion outside the electrolyte is (a) higher than, (b) the same as, (c) lower than, that of the inside portion.
10. .... In a voltaic cell, a current that flows consists of the movement of (a) negative ions only, (b) positive ions only, (c) both positive and negative ions.

The results have been very much the same as in the case of the M.S. examination. There has been a wide spread in grades, ranging from somewhere in the neighborhood of +80 to −20. To the weak student, the evidence which his paper presents is generally rather convincing. A number of such candidates have concluded at once that their showing was unsatisfactory and that it would not pay to try further; others have been inclined to doubt the correctness of the predictions as to their ability in physics, and for them the questions asked and the answers given have been invaluable as starting points for discussion. On the other hand, many have shown by their tests their general satisfactory preparation and have been permitted and encouraged to go on with the work for the advanced degree.

More so than in the case of the master's examination, the Ph.D. preliminary has helped us to discover those who are able to talk more or less glibly regarding matters covered in graduate courses, such as damped linear vibrations, precession, principle of least action, divergence of a vector and entropy, but who are uncertain as to the fundamentals of undergraduate physics, and who are stopped by questions such as 1, 6, 7, 92 of the M.S. list. In a way, such students have superstructures but lack proper foundations. That there are such people was quite surprising to us when we first found them, but that there are such there is no doubt. We look upon our objective tests for graduate students, together with the follow-up discussions, as the surest means of finding who they are.

At the University of Pittsburgh, those of us who have tried the objective test are generally quite strongly in favor of it, for both the undergraduate and the graduate. Further, although we are not inclined to rely wholly on such tests, we believe that objective tests have the particular advantage of revealing in a relatively short time and with at least equal clarity to both instructor and student that which can only be revealed conclusively in tests of the classical type which involve a much greater length of time.

The Importance of Physics in the College Curriculum[1]

WILFRID J. JACKSON, *Department of Physics, N. J. C. Rutgers University*

IT would seem appropriate in these early days of the American Association of Physics Teachers, to give some time to a consideration of the place of the introductory physics course in the college curriculum. We are all familiar with the considerations which at present give physics a place in the curriculum of practically every college and university. Among these is the widespread conviction that men and women in our institutions of higher learning should come to some understanding of the empirical laws of the physical world; the feeling that students should become familiar with the scientific method, because through it they may come to appreciate the scientific spirit which is a major force in our society today; the fact that physics is in some cases essential for professional training.

Valid as are these considerations, the question is: Do they cover the teacher's real responsibility toward his students? My own answer to this question, the result of personal teaching experience, would be that the major responsibility is rather the more inclusive task of training men and women to think clearly and so to become truly intelligent beings, people capable of a comprehensive outlook and a sensitiveness to all human and other problems. This sounds extremely idealistic, but it will become clear I think, as we proceed in our analysis, that the study of physics is well adapted to the accomplishment of this task.

At the outset, the teaching of physics entails presenting to the student a certain body of facts together with the technical terminology of the science. The facts of physics as ordinarily given in the introductory course connect readily with the student's experience for the most part, and for this reason physics makes a very good introduction to the study of the sciences and the scientific method. Incidentally, it might be noted, that students in science are very apt to consider recent information as final, failing to realize that more exact measurements or data collected under slightly different conditions will give a new body of facts requiring possibly a fundamentally different outlook for their interpretation.

Needless to say, in order to pursue the study of any science one must learn the language or terminology peculiar to that science. In this sense mathematics, physics, or any of the sciences, is as much a foreign language as is French or German to the English student. The facts of any science, we well know, are usually expressed in technical language with terminology which the student must understand if he is to have an adequate appreciation of the subject matter and know how to correctly apply it. This requires strict mental discipline which in itself is another good reason for having students study physics.

If the study entails nothing other than the presentation of facts and the understanding of the technical terminology, it would not necessarily meet the criterion of the teacher's responsibility, which is his concern for stimulating in students vital intellectual activity. This concern must always motivate his whole teaching if students under his guidance are to be trained to think clearly. Even though one has this attitude toward the teaching of physics one may essentially fail unless certain things are kept in mind.

At this point in our analysis it might be well to remind ourselves of some specific difficulties that all of us are likely to encounter. Students in general have the habit of using terms which are hazy in their own minds. This makes for loose thinking for they have never really grasped the ideas which the terms represent. Everyone has had the experience of having a student think that he was explaining a physical phenomenon, when in reality he was hopelessly caught in a net of technology.

All are aware that the mechanical use of formulas or relationships and the use of rule of thumb methods in the solution of problems give

[1] Read before the American Association of Physics Teachers at the Atlantic City meeting, December 29, 1932.

the student little mental training of real and lasting value. When he is made to state the problem in his own words and to proceed logically step by step to solution, the result for him, even if he is not of the highest caliber, is quite worthwhile. In the face of the meager training of this kind given to students nowadays this is an exceedingly difficult and in some cases, an almost hopeless task to accomplish.

For the young student physical phenomena divorced entirely from his experience of them is of little interest. The alert student may observe for himself without the aid of special apparatus many of the phenomena, it would be rash to say all, usually described in the elementary texts if he is stimulated to do so. If he becomes observant he will take an entirely different attitude toward the subject matter of physics. Having the student acquire the habit of pausing and questioning himself, in all of his reading and observation, or in other words to learn to sense a problem, will aid immensely in developing his powers of observation.

A major difficulty frequently arises in having the student draw inferences from a given set of observations. Even when the task is clearly set as a problem of verification, few students apparently are capable of stating clearly just what the experiment has indicated. This difficulty is doubtless aggravated by the fact that some laboratory manuals are so designed that they may direct the attention of the student to the printed page and a set of rigid instructions which he thinks he must slavishly follow, instead of encouraging him to give his attention to the experiment itself.

A problem arises in connection with the demonstration lecture when it unwittingly becomes too entertaining. If designed to demonstrate clearly and to present simply and logically, a portion of subject matter in such a way as to demand the concentrated attention of the students it is doubtless of very real value.

Teachers in every field ofttimes do not take time to deal with specific student needs as they arise, because of the feeling that a certain amount of ground must be covered according to the prevalent ideas as to what constitutes any particular course. Frequently this occurs at the expense of the student's fundamental understanding.

In fulfilling what we have here considered to be our major responsibility as physics teachers, namely, that of teaching students how to think accurately and comprehensively, we realize full well that there are many difficulties aside from the actual teaching itself that are in some respects beyond our immediate control. For example, few students entering our colleges are so trained that they respond readily to this type of teaching, and many are reluctant to be stimulated to any form of intellectual activity. Furthermore, teachers in the various fields do not expect and exact a uniformly high degree of intellectual response and cooperation on the part of the student. All faculty members doubtless share to a large extent this idea of the fundamental purpose of all teaching, but it would appear that they do not see physics as carrying this out especially. For the most part they regard it of value only to those specializing in science or requiring it for professional purposes. Many students hold this same point of view for they do not see any cultural value in the general physics course, and those who elect it are most likely to do so for reasons quite apart from the one suggested here as the most important reason for taking any college course.

We physics teachers, noting the caliber of the students entering our first year courses, either because of requirement or out of choice, have perhaps considered the general run as a necessary evil, whereas, those very students may be in the greatest need of the kind of training given in a physics course, under the proper kind of instruction.

In conclusion: These difficulties are by no means insurmountable. However, they do present a challenge to the American Association of Physics Teachers which is most assuredly interested in the improvement of technique in the teaching of physics, and also in having the science play the important rôle it should in our colleges and universities. Progress may be achieved through a more general recognition of the fundamental training it can give in clear and comprehensive thinking.

The Perspective of Experimental Fact, Empirical Law and Theoretical Interpretation in the General Course in Physics[1]

THOMAS D. COPE, *Department of Physics, University of Pennsylvania*

FOR the vast majority of students pursuing physics in college, the general course of one year's duration represents their only formal contact with the science. A textbook for such a course written forty years ago comes to mind. The author was a distinguished professor, a one-time president of a national society devoted to a science, a fellow of learned bodies, including the National Academy, a scientific man well known and well acquainted on both sides of the Atlantic.

Part Four of this book is entitled "Physics of the Aether." It begins by describing the aether. The chapter-headings read:—

1. Energy of Aether-vibration—Radiant Energy.
2. Energy of Aether-stress—Electrostatics.
3. Energy of Aether-vortices—Magnetism.
4. Energy of Aether-flow—Electrokinetics.

To our author the aether was a logical necessity. For him it existed.

Most of the boys who used this book in college in the nineties and for a few years in the present century are alive. Their children are in college or have been there recently, and the fathers have learned from the children that the aether of 1892 was "a subtle fluid invented by a man to transmit his misconceptions from one place to another."

For years, and particularly during the last twenty-five years, so much has been said and written about the machinery of physics, that the present writer entertains the belief that many contemporary textbooks for the general college course might well reflect the results of these studies to a greater extent than now appears to be the case. The textbook of forty years ago entangled fact and empirical law with a scheme for their interpretation. For instance, it defines radiation as "the transference of energy by means of periodic disturbances in a special medium filling all space and called the aether." Your writer maintains the thesis that many current textbooks might profit by the example of the book he has mentioned.

To allay misgivings assurance is offered that the writer will not venture into the fields of structure of matter and theories of radiation except to remark that he read a recent editorial[2] entitled *Cosmic Ray Romancing* with amusement and no feelings of righteous indignation. Scientific "romancing" is an honorable and indispensable pursuit. Without it progress seems to halt. Trouble begins when experimental fact, empirical law, and romancing are so entangled that the general reader and the callow student are at a loss to know where one ends and another begins.

Trouble dissolves when the three are set forth in bold relief. Eddington's "two tables"[3] is a masterpiece of such exposition. One table is empirical, the other "romantic." More "Eddington" is needed in the textbooks. Let the aether, for instance, be presented as a bit of romancing, a construct of the scientific imagination, a praiseworthy attempt to interpret, an intellectual tool to be used for what it is worth, and until a more useful tool shall have been fashioned.

To the professional physicist all this may be trite. The editorial of September 18th shows that to the reading public it is not so commonplace. Your writer includes the student in the general course among the reading public.

In view of the prominent part taken in recent literature by discussions of the scientific method, and of the nature of physical concepts and physical theories, it is suggested that a chapter devoted to these subjects be given a place near the beginning of the textbook of general physics. This chapter should be supplemented by references for wider reading. It should be referred to

[1] Read before the American Association of Physics Teachers at the Atlantic City meeting, December 29, 1932.

[2] New York Times, September 18, 1932; see also Science **76**, 276 (1932).

[3] Eddington, *Nature of the Physical World*, Introduction.

again and again as the course develops. It should grow upon the student, giving meaning to concepts and theories as he encounters them. It would seem better to introduce these questions and to acknowledge their existence in the course in general physics, than to leave it to courses in philosophy to reveal to the student the nature of the mental operations he is asked to perform in the physics course.

For the purposes of illustration a few topics are selected. For the general course geometrical optics has long appealed to the writer as ideal. The laws are empirical laws, descriptive of phenomena to high approximations. They are not entangled with any theory of the nature of light. All this is clear to the student, and it is also clear to him that any adequate theory, past or future, must account for these laws. The successes and failures of two historical theories are admirable lessons in the scientific method.

In physical optics the situation is usually not so happy. Fact, empirical relations, and theory are more or less entangled. In an effort to establish a perspective the writer for some years has taught the familiar experiment "wave-length by diffraction grating" as establishing an empirical correlation between each spectral line and a length—in air as the medium, of course. A group of students equipped with replicas of different grating-constants, and observing illuminated slits from various distances can in two hours establish such correlations for a few lines in a convincing manner. Other operations establish the same correlations. Theories may come and theories may go but these correlations will stand. The undulatory theory furnishes an interpretation, which the future may or may not supplant.

Has not the free fall of particles at the surface of the earth with a common acceleration at the same place earned a promotion from the rank of breeder of problems in constant acceleration, to the rôle of a challenging empirical fact? Is not the mutual attraction between earth and particle to be presented as an attempt at interpretation, highly successful but not entirely so? Are not the signs already at hand that other interpretations are conceivable? And is it not pertinent to remark to the student in the general course that we are now at the two hundred and fiftieth anniversary of the publication of the *Principia;* that two hundred and fifty years hence the five hundredth will be upon us; that in all likelihood particles will fall then as they fall now; but that not even Sir Isaac himself, were he alive, could foretell how the phenomenon will then be looked upon?

Newton's laws of motion have been studied by Mach, Pearson, and many others. Would it not assist in the general course if the textbook should present these laws from the standpoint of the constructive criticism they have received, pointing out what is definition, what is convention, and what has an empirical basis? Many a conscientious student has taxed his brain with these laws, and has found himself lost in the entanglement.

These topics are presented as random samples of a great number of topics which might be selected from the general course. In all of them intellectual fairness to the undergraduate would seem to suggest that the perspective of fact, empirical relation, and interpretation be more sharply drawn.

APPARATUS, DEMONSTRATIONS AND LABORATORY METHODS

A Shadow Projection Lamp for Electroscope and Radiometer[1]

IF an ordinary gold leaf electroscope or a Crookes' radiometer is to be shown to a large class some means of projection must be used if the class is to follow the operations in detail. Images of these bulky instruments cannot conveniently be projected with an ordinary lantern and such projection is at best a bit clumsy. A more convenient and satisfactory means of projection is obtained by using a point source of light of high intensity to cast a sharp shadow of the entire apparatus on the wall. In this way the complete image of the entire electroscope as well

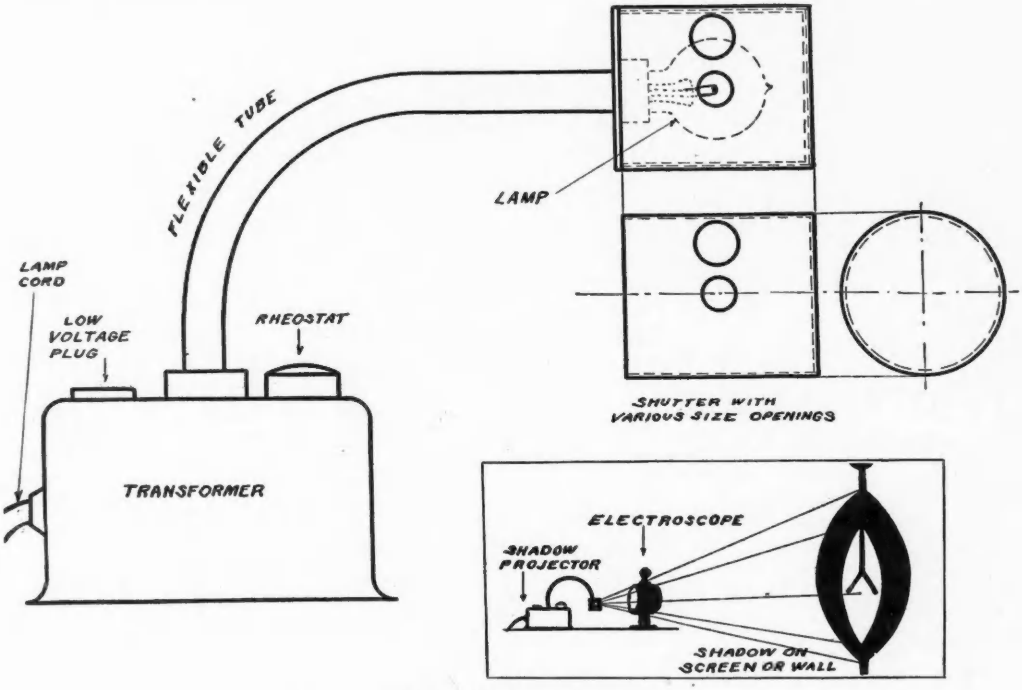

FIG. 1. Shadow projector.

as the charging operations with the charging rod can be easily projected while the process of charging is being explained.

An automobile headlight bulb affords a sufficiently small and intense source of light for a sharp shadow. A very handy shadow lamp is therefore made by using as a base a small 110–8 volt transformer, from the top center of which

[1] Read before the American Association of Physics Teachers at Atlantic City, December 29, 1932.

rises a flexible metal conduit terminating in the light socket and headlight bulb. (Fig. 1.) The bulb is completely enclosed by a small metal cover having circular openings of different diameters. A small short-focus lens is also attached by a side tube, not shown in the figure, so that a narrow beam of nearly parallel rays may be obtained when desired.

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A Dark Frame for X-Ray Photography[1]

IN making an x-ray photograph before a class the problem of developing and fixing the plate without leaving the room and breaking the continuity of the lecture arises. A plate holder with meandering light-proof openings in the top and bottom of the frame permits the solutions to enter and leave the interior without admitting the light. In this way it is possible to use the plate holder as the x-ray camera and then place it immediately in the developer and proceed with all the washing and fixing operations in a lighted room.

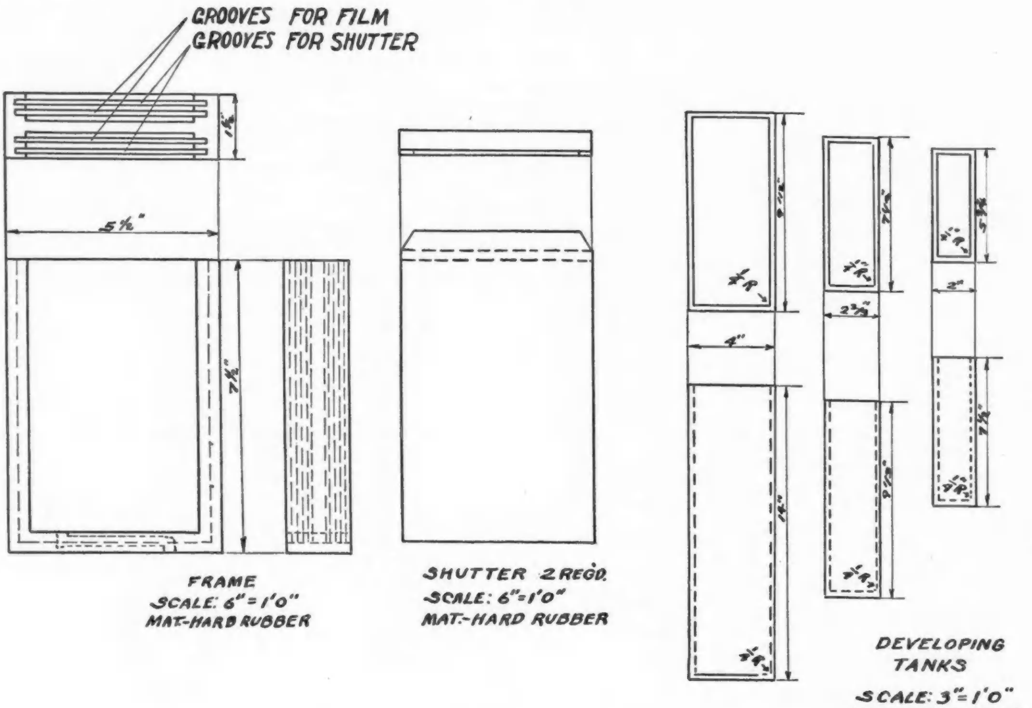

FIG. 1. X-ray dark frame and developing tanks.

Fig. 1 shows the design which differs little from that of an ordinary plate holder. This device is made of hard rubber so that it may be thoroughly washed after use and it has the crooked openings at top and bottom which permit the fluids to enter and leave; otherwise it is an ordinary plate

[1] Read before the American Association of Physics Teachers at Atlantic City, December 29, 1932.

holder. The shutter has a small flange at the top to shut out the light on the grooves. If two films are used it is desirable to use leaded rubber or else to have a thin lead sheet at the center of the frame between the films; the exposure of one film for a second will not permit enough energy to reach the unexposed plate to fog it.

Ordinary developing trays may be used but hard rubber tanks which telescope into each other when not in use are better.

With this device the lecturer may continue directly with his explanations of x-ray phenomena or may insert a few words regarding the photographic processes without the loss of interest which will come if he leaves the room or has an assistant develop the film.

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Demonstration of the Variation of Electrical Resistance with Temperature

THE apparatus whose description follows was developed in response to the need for a device for lecture demonstration which is easily set up, inexpensive, readily understood by the student, and is striking in its performance.

The circuit consists simply of three dry cells, a 3.8-volt, 0.3-ampere flashlight lamp, and a coil consisting of about 325 cm of 0.022-cm diameter iron wire. If the iron wire were heated unprotected in a Bunsen flame, it would be destroyed in a short time; in order to overcome this difficulty, the wire was space-wound on a piece of porcelain insulator tube 4.5 cm long and 1.6 cm in diameter, provided with convenient terminals for connection. The coil was then covered with "Insalute" cement, to keep the air from the iron wire. (This work was done at small cost by the Rubicon Company of Philadelphia.) The actual arrangement is shown in Fig. 1, where A is the resistance coil, B a shortened Bunsen burner, C the miniature lamp and socket, and D a hard rubber or Bakelite support for the connections.

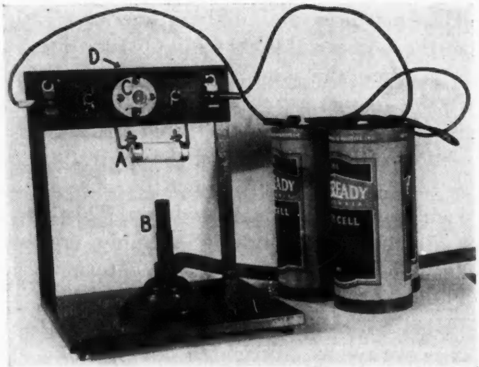

FIG. 1. Apparatus for demonstrating the effect of temperature upon resistance.

Set up as indicated, at room temperature the lamp glows conspicuously but not quite at normal brightness. When the resistor has been heated for a short time the lamp is completely extinguished. Upon cooling the resistor in liquid air or solid carbon dioxide the lamp glows at slightly more than normal brightness. The resistance varies from about 3 ohms in liquid air to about 50 ohms in a Bunsen burner. The apparatus has been used successfully to demonstrate the phenomenon to classes of one hundred students.

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DISCUSSION AND CORRESPONDENCE

Note on the Velocity of Sound

In any of the standard textbooks of college physics we may read that the velocity of sound is given by $(E/\rho)^{\frac{1}{2}}$ where E is the modulus of elasticity for compression and ρ is the density of the medium. It is usually explained that the compressibility modulus is the one associated with adiabatic compression which is equal to κp, where κ is the ratio of the specific heat at constant pressure to that at constant volume, and p is the pressure.

That one uses the adiabatic modulus rather than the isothermal is then usually attributed to the fact that the sound vibrations are so rapid that the temperature inequalities do not have time enough for equalization. But with regard to the effect of heat conduction the contrary is the case—the vibrations are much too slow for approach to the isothermal condition. This fact is not altogether new but is certainly not well known, at least in the field of elementary physics teaching.

To get a clear view of the matter let us think that the wave is propagated adiabatically and consider how heat conduction works toward making the process isothermal. The maxima and minima of temperature occur in different wave-fronts which are spaced at intervals of $\lambda/2$ where λ is the wave-length. The change from maximum to minimum temperature at any particular place occurs in the time $\lambda/2v$ where v is the speed of wave propagation. From the theory of heat conduction we know that the distance d in which a considerable alteration of temperature penetrates during the time t is

$$d \sim (kt/s\rho)^{\frac{1}{2}}$$

(here $\sim$ means "of the order of magnitude of"), where k is the thermal conductivity, s the specific heat and ρ the density. Therefore if heat conduction is to cause appreciable departures from adiabatic behavior, conditions must be such that the distance a temperature inequality penetrates in time $\lambda/2v$ is comparable with $\lambda/2$, the actual distance apart of the places of maximum and minimum temperature. This leads to the result

$$\lambda \sim 2k/s\rho v.$$

This result is more illuminating if we substitute for k its value as given in the kinetic theory of gases. There it is shown that the heat conductivity is of the order of the product of the specific heat, the density, the mean speed of the molecules and the mean free path, l. It is well known that the velocity of sound is of the order of the mean speed of the molecules. Therefore we have the result that

$$\lambda \sim l.$$

In other words, the effect of heat conduction comes in for waves of such very high frequency that the wave-length of the sound waves is comparable with the mean free path of the molecules; that is, about 10^{-5} cm. Of course the ordinary wave theory which treats the gas as a continuous medium breaks down at such frequencies but even this rough argument makes the point that ordinary sound is of too low rather than too high frequency for conduction to be effective.

Looking now to the literature of acoustics on this topic I find that Rayleigh[1] has treated the effect of conduction on the propagation of sound waves and finds the main effect to be an absorption. His formula (18) shows that the amount of absorption introduced through the operation of heat conduction becomes appreciable only at the frequencies of the order of those given by the rough considerations of the preceding paragraph. But the result does not seem to have found its way into any of the textbooks. Herzfeld and Rice[2] have noted the point in connection with studies on supersonics and commented on the general prevalence of the erroneous view of the matter.

The point is not generally known, however, and the interesting connection of the wave-length with the mean free path of the gas seems not to have been pointed out before; these are the excuses for writing this note.

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[1] Rayleigh, *Theory of Sound*, II, 28.

[2] Herzfeld and Rice, Phys. Rev. **31**, 691 (1928).

Introductory Acoustics

Introductory Acoustics. George W. Stewart. Pp. 195+xi. D. Van Nostrand Company, Inc., New York, 1932. Price $2.75 (Paper cover).

APPLICATIONS of the fundamental exact sciences are being made in an ever increasing number in other fields of knowledge. The applications in other branches of "natural science," both pure and applied, have long been recognized but we now seem to be in an era when the applications are increasing at an astounding rate—information must, if possible, be expressed in equational form. In other fields of learning, usually not classed as science, the methods or the facts, or both, of the exact natural sciences are being employed.

It is thus becoming of ever increasing importance to supply training in the exact sciences, which include mathematics, to those who will not work in these fields but who must use the methods and at least a part of the principles and facts. Many of the branches of learning, in which applications of exact science are being made, are themselves increasing in content very rapidly. Students in these fields do not seem to feel that they can afford to spend the time studying general courses in mathematics, physics and chemistry because they are going to apply so little of them and because they must have the time to study the numerous latest developments in their own special fields and more closely related fields. And if a student does take the "first college courses" in these three fields of exact science, he will not, in general, have learned enough about those parts which concern his particular applications to enable him to carry them out. He must therefore study one or more "advanced courses" for which he is certain he has no time.

Although our whole body of knowledge has increased many fold during the last half century, our "college course" consists now, as it did then, of four terms of thirty-six weeks each. It seems evident that we must either increase the length of time alloted to general education before specialization, or we must specialize our "general" education to a much greater extent so that each student may get a suitable background for his particular field of study. The latter is already taking place.

One very successful attempt to meet this situation by the second method has been made by Professor George W. Stewart of the University of Iowa. Professor Stewart opens the preface to his *Introductory Acoustics* with the following paragraph: "The accompanying text is an elementary treatise that undertakes to consider the most common phenomena in acoustics. The content assumes no previous preparation in physics, and utilizes very few mathematical expressions. The limitation in preparation of the student is met by the insertion in the text of the meaning of each technical term at the point where it is first employed." He wrote the book after several years of experience in presenting the subject of acoustics to students of "music, speech and psychology."

This textbook covers a much larger part of acoustics than do textbooks of College Physics which, on the average, devote less than one-third as much space to wave motion and sound. In spite of this it contains much less information in equational form. In fact only twenty equations appear in the book and of these only two are derived—the relation between wave-length, velocity and frequency, and the expression for the temperature coefficient of velocity. Graphs are used freely to show various functional relationships.

From such a description one might be led to believe that accurate reasoning would not be used and that "problems" could not be introduced. This is decidedly not the case. At the end of each of the first eight chapters occur, on the average, thirteen questions, and a total of 143 questions appear in the book. Very few of these require calculations, and therefore statements in equational form. Nevertheless, the problems on the whole are not too easy; many require very careful thought and visualization in addition to more than average ingenuity.

Great care seems to have been taken to avoid inaccuracy of statement, which method is so often employed to achieve apparent elementariness of content. In a number of cases the author even goes so far as to point out the fallacy which is likely to be derived by an improper application of the principles or facts stated.

More than seventy-five specific references to original papers and standard treatises on sound are given at appropriate places throughout the book. Unfortunately such citations are almost unknown in other elementary textbooks. As a consequence a first-year student reads his textbook, perhaps another equally inadequate treatment in another elementary book, and drops the subject. Specific references to authoritative books and original papers will satisfy the interests and the needs of the beginning students.

Seven reproductions of photographs, seventy-five figures and eight tables illustrate the book. A complete Table of Contents is given; therefore the lack of an index is not serious in a book of only 195 pages. The titles of the fifteen chapters are: Sound Waves, Reflection and Absorption in Auditoriums, Acoustic Reflectors, Refraction and Diffraction, Phase Change at Reflection, Resonance, Musical Sounds, The Nature of Vowel Sounds, Certain Physical Factors in Speech, Audibility, Binaural Effects, Acoustic Transmission, Selective Transmission, Musical Scales, and lastly Musical Instruments, the Voice and other Sound Sources.

Professor Stewart's book is decidedly not an enlarged high-school textbook; he even suggests that the students should be juniors or seniors in college. It should prove to be exceedingly interesting and valuable to students whose fields of interest touch some parts of acoustics. It provides excellent supplementary reading for certain students of college physics and for high school teachers of physics and general science. It is to be expected that books of this type, treating other parts of the exact natural sciences, will appear and will be used with equal success.

William Schriever
Department of Physics
University of Oklahoma

Brief Notices of Recent Publications

An Outline of Atomic Physics. Members of the Staff of the University of Pittsburgh. Pp. 348+vi, Figs. 158. John Wiley and Sons, New York, 1933. Price $3.50.

One of the few textbooks on modern physics that is adapted to the needs and capacities of students who are not majoring in physics and who have had but one year of college physics. Calculus is avoided but simple mathematics is employed freely. There are problems at the end of each chapter.

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The Elements of Physics. Alpheus W. Smith, Professor of Physics, Ohio State University. Third edition. Pp. 778+xviii, Figs. 724. McGraw-Hill Book Co., New York, 1932. Price $3.75.

This book appeared in 1923 as *Elements of Applied Physics* and in 1927 as *Elements of Physics*. In the present edition many sections have been rewritten and over one hundred pages have been added. The number of examples of the applications of physics to other fields of knowledge and to everyday life is unusually large. There are many solved numerical problems.

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Experimental Physics for Colleges. Walter A. Schneider, Associate Professor of Physics, and Lloyd B. Ham, Assistant Professor of Physics, Washington Square College, New York University. Pp. 259+ix, Figs. 163. The Macmillan Co., New York, 1932. Price $2.25.

A laboratory manual for the general course. It is divided into chapters, each of which begins with a theoretical discussion of the several experiments contained in it. Problems accompany each experiment and the student is expected to solve these before coming to the laboratory. Simple and inexpensive apparatus is employed.

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A Laboratory Manual of Experiments in Physics. Leonard Rose Ingersoll, Professor of Physics, University of Wisconsin, and Miles Jay Martin, Associate Professor of Physics, Milwaukee Extension Center, University of Wisconsin. Third edition. Pp. 301+ix, Figs. 113. McGraw-Hill Book Co., New York, 1932. Price $2.50.

This well-known first-year college manual has been completely rewritten and about forty percent of new material has been added. A brief digest of underlying theory accompanies each experiment. The instructions are somewhat more specific than in former editions but the authors seek to avoid "cookbook-like instructions" which leave nothing to the ingenuity of the student.

Engineering—a Career—a Culture. Education Research Committee of The Engineering Foundation. Pp. 61+iii. The Engineering Foundation, 29 West 39th St., New York, 1932. Price $0.15 (Paper cover).

A high-grade vocational guidance pamphlet. The topics discussed are: engineering requirements and opportunities; preparation for engineering, earnings of engineers; the nature of each of the several branches of engineering. Beautifully printed. Illustrated with ten pen and ink drawings.

Experimental College Physics. MARSH WILLIAM WHITE, Associate Professor of Physics, Pennsylvania State College. Pp. 283+xi, Figs. 166. McGraw-Hill Book Co., New York, 1932. Price $2.50.

A laboratory manual for the general course. Each experiment is introduced by a complete statement of the underlying theory. In many cases solved examples are included with the theory. A large number of well-chosen problems, and review questions of a qualitative nature, accompany each experiment.

Proceedings of the American Association of Physics Teachers

MINUTES OF THE ATLANTIC CITY MEETING, DECEMBER 29–31, 1932

THE second annual meeting of the American Association of Physics Teachers was held in Atlantic City on Thursday afternoon, Friday afternoon and Saturday morning, December 29–31. President Homer L. Dodge, and Vice-President Frederic Palmer, Jr., presided. The sessions were held in the Japanese Room of the Ambassador Hotel.

THE SESSIONS FOR THE READING OF PAPERS

At the Thursday afternoon session papers were presented as follows:

The Perspective of Experimental Fact, Empirical Law, and Theoretical Interpretation in the General Course in Physics.—PROFESSOR THOMAS D. COPE, *University of Pennsylvania.*

A Simpler and More Accurate Acceleration Measurement.—PROFESSOR R. L. EDWARDS, *Miami University.*

New and Improved Lecture Apparatus, (a) Apparatus for Projecting Phonedeik Oscillations, (b) A Shadow Projection Lamp for Electroscope and Radiometer.—PROFESSOR J. G. BLACK, *Morehead State Teachers College.*

New and Improved Lecture Apparatus, (a) An Apparatus for the Electrolysis and Synthesis of Water, (b) A Dark Frame for X-ray Photography.—PROFESSOR J. G. BLACK, *Morehead State Teachers College.*

The Importance of Physics in the College Curriculum. —PROFESSOR WILFRID J. JACKSON, *Rutgers University.*

Laboratory Investigation versus Laboratory Verification.—PROFESSOR C. R. FOUNTAIN, *George Peabody College.*

What is a Cultural Physics Course.—PROFESSOR R. J. HAVIGHURST, *Ohio State University.*

Accessories for Portable Spectroscopes and Spectrometers Used in Undergraduate Instruction.—PROFESSOR A. N. LUCIAN, *University of Pennsylvania.*

Student Errors in College Physics.—PROFESSOR C. J. LAPP, *State University of Iowa.*

A Survey Course in Physics for Seniors in Engineering. —PROFESSOR MARSH W. WHITE, *Pennsylvania State College.*

The Friday afternoon session was devoted to invited papers. In a paper entitled *Training in Physics*, Doctor W. F. G. Swann, of the Bartol Research Foundation, emphasized the importance of having the student understand thoroughly the relatively few fundamental concepts of physics, rather than having him spread out over the whole field. In discussing the amount of time that an instructor should give to his research students, Doctor Swann remarked that a year's floundering on the part of a student beginning research may possibly be very good training. Shopwork is very valuable training for research, for then the worker will know how to design apparatus. The beginner in research should also be given a proper appreciation of orders of magnitude. He should be taught to develop skill in overcoming difficulties and should be made to realize that the amount accomplished is proportional to a high power of the intensity rather than to the product of intensity and time. He should not be discouraged from trying experiments that are denied by theory, provided the experiments lie on the borderline of the theory which happens to be current at the time. In the discussion that followed this paper, Professor A. H. Compton, of the University of Chicago, remarked that the simplified explanations of phenomena which are employed in elementary instruction are seldom the original ones. It is necessary to employ such explanations in order to save time and expedite instruction, but there is a danger from excess simplicity; the student must learn that it is not always by simple and obvious methods that discoveries are made.

Professor H. B. Williams, director of the department of physiology, Columbia University, spoke on *Physics for Premedical Students*. He did not recommend that a special type of physics be taught premedical students. On the contrary, these students need all the fundamentals that constitute a well-rounded course in physics. The main point is that the student be made to understand that the course in physics is actually part of his medical training. By including in the course a number of specific applications of physics to the medical sciences, and possibly also a few special experiments, interest will be awakened and the student will be convinced that he is beginning his study of medicine while still in physics. Professor H. W. Farwell, of Columbia University, in leading the discussion of this paper, pointed out that if practicing physicians find no use for physics, it is probably because their medical professors never used it; there must be more medical men who are appreciative of the value of physics, as well as professors of physics who are sympathetic toward the problems of premedical training.

Facing Reality in the Teaching of Magnetism was the subject of a paper by Professor D. L. Webster, of Stanford University. Professor Webster referred to the curious paradox that, whereas physics is satisfying because in it we deal with realities, there also exist and are employed in the science many concepts that are not realities. An example is the concept of poles in magnetism. The question arises as to whether we are justified in continuing to employ such concepts after we have learned that they are unrealities. Magnetism can be taught without the use of the concept of poles. Perhaps the concept of poles should be employed in elementary treatments, but if so, only in a subordinate rôle. In the discussion that followed, Professor Anthony Zeleny, of the University of Minnesota, expressed the opinion that the concept of the pole should be employed but that it should be kept constantly in mind that it is an unreality.

Professor A. G. Worthing, of the University of Pittsburgh, in a paper entitled *The Usefulness of Objective Tests of the Reasoning Type*, described the tests in physics which are in use at the University of Pittsburgh. The multiple-choice type of test is employed and the questions are for the most part of the reasoning type. The discussion of this paper was introduced by Professor F. L. Brown, of the University of Virginia, who pointed out the desirability of using such tests because of their comprehensive nature and because of the quickness with which tests given to large classes can be graded.

At the Saturday morning session, Professor R. L. Petry, of the University of the South, gave a paper on *Animated Blackboard Diagrams*, which he illustrated by means of motion pictures taken with amateur equipment.

On behalf of the University of Chicago, Dr. Paul E. Klopsteg, of the Central Scientific Company, introduced the new University of Chicago sound films *The Molecular Theory of Matter* and *Oxidation and Reduction*. The films were exhibited by Mr. Rollin D. Hemens, of the University of Chicago Press. (See Fig. 1.)

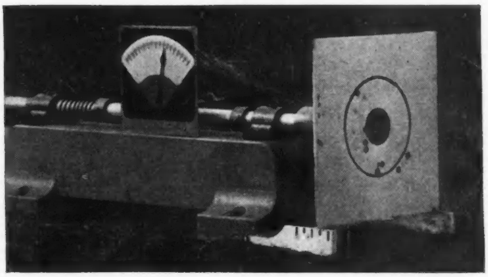

FIG. 1

A scene from the University of Chicago sound film "The Molecular Theory of Matter." The steel target is connected with a gauge which registers the force exerted by cumulative impacts of machine gun bullets on the plate. This helps to make clear how the continuous bombardment of gas molecules exerts pressure on the walls of the gas-container.

The remainder of the Saturday morning program was given over to informal reports of the following standing committees of the Association: the committee on differentiation in first-year courses; the committee on preparation in mathematics; the committee on visual education; and the committee on the ideal undergraduate curriculum.

Meetings of the Executive Committee

THE executive committee held meetings on Friday afternoon, December 30, and on Saturday morning, December 31. Members of the committee who were present were Professor Homer L. Dodge, Professor Frederic Palmer, Jr., Doctor Paul E. Klopsteg, Professor F. K. Richtmyer, Professor O. H. Blackwood and Professor W. S. Webb. Professor A. G. Worthing was also present as a representative of the Physics Teachers of Western Pennsylvania and environs.

The following persons were elected to membership in the Association: Professor Robert S. Shaw, City College of New York; Professor James A. Swindler, Westminster College; Professor W. P. Boynton, University of Oregon; Professor Joseph S. Knapper, Albright College; Professor K. G. Larson, Augustana College; Professor G. A. Van Lear, Jr., University of Oklahoma.

The president reported that the correspondence with members of the executive committee with reference to the proposed journal had resulted in the appointment of a journal committee consisting of Professor Wm. S. Webb, *chairman*, Professors F. C. Blake and D. L. Webster and Doctor Paul E. Klopsteg. Professor Webb presented the report of the committee in the form of an elaborate fourteen-page plan for an official journal and a three-page abstract of the plan. Several modifications in the plan were discussed and the report of the journal committee was approved with certain minor modifications. The executive committee adopted the following resolutions:

1. It is the opinion of the executive committee that the early publication of a journal is essential to the success of the Association.

2. It is the opinion of the executive committee that the annual dues should be $3.00 for 1933 and at least $4.00 thereafter.

The secretary was instructed to present these resolutions to the business meeting of the Association as expressions of opinion rather than as recommendations of the committee.

President Dodge reported that the vote of the executive committee was unanimously in favor of paying the travel expense of the secretary to the Atlantic City meeting and he explained that this action was taken without the knowledge of the secretary.

The following plan for conducting the annual election of officers was adopted. The secretary is to request the membership, in a nominating ballot, to submit names of members who should be considered for office; names are to be listed in order of preference, without regard to any particular office. This information is to be tabulated by the secretary and sent to the nominating committee. The nominating committee is appointed by the executive committee at each annual meeting and it is to serve for the year that follows. It is the duty of the nominating committee to consider the tabulated information obtained from the nominating ballots and to prepare a ballot which specifies one nomination for each office to be filled. Space is to be provided on the ballot so that other names can be written in and voted for by any member of the Association. The secretary is to mail this ballot to the members in time to receive and count the vote, and report the results at the annual meeting of the Association.

The nominating committee for 1932 was appointed as follows: Doctor Paul E. Klopsteg, *chairman;* Professor C. J. Lapp; Professor F. L. Brown. This committee was requested to serve for the year 1933 also and to receive the nominations and prepare the ballot for the officers for 1934.

The president was authorized to appoint a committee on regional chapters which is to make plans for fostering and supervising the organization of regional chapters in accordance with the constitution of the Association.

It was voted to transmit to the annual meeting of the Ameriacn Institute of Physics the following nominations of members of the Association to be put up for election as members of the Governing Board of the Institute, each with term as stated: Professor H. L. Dodge, term to expire February 1934; Professor Frederic Palmer, Jr., term to expire February 1935; Doctor Paul E. Klopsteg, term to expire February, 1936. It was voted that the president and secretary should designate a proxy to represent the Association at the annual meeting of the members of the American Institute of Physics to be held in

February, 1933. Professor Palmer was so designated.

At the Saturday morning meeting of the executive committee, the nominating committee reported nominations as follows: for president, Professor Frederic Palmer, Jr., for vice-president, Professor D. L. Webster; for secretary, Professor Wm. S. Webb; for treasurer, Doctor Paul E. Klopsteg; for members of the executive committee, to serve two years, Professor T. D. Cope and Professor F. K. Richtmyer; for members of the executive committee, to serve one year, Professor L. R. Ingersoll and Professor B. A. Wooten.

It was decided to sponsor luncheon meetings for members at those meetings of the American Physical Society at which the Association has no special programs.

Professor Duane Roller, of the University of Oklahoma, was made editor of the proposed journal.

The president was authorized to appoint a committee on the teaching of physics for premedical students.

The Annual Business Meeting

THE regular annual business meeting of the American Association of Physics Teachers was held on Saturday morning, December 31, 1932, at 10:10 A.M. in the Japanese Room of the Ambassador Hotel.

President Dodge made a statement concerning the accomplishments of the Association during the past year. He pointed out that the A.A.P.T. is one of the founder societies of the American Institute of Physics, and that, beginning January 1, members will receive the *Review of Scientific Instruments with Physics News and Views*. The attitude of the executive committee toward the question of publishing an official journal of the Association was explained and Secretary Webb read the report of the journal committee, as approved by the executive committee.

President Dodge explained further the purpose of the proposed journal and called for a reading of the part of the minutes of the executive committee which referred to the journal. After the two resolutions of the executive committee were read, Professor Lapp, of the State University of Iowa, moved that the body approve the report of the journal committee as presented by the executive committee and concur in the opinions expressed by the executive committee. The motion was seconded by Professor Brown, of the University of Virginia. There was considerable discussion as to the advisability of initiating a journal at the present time if by so doing it became necessary to raise the annual dues. Professor Patterson, of Rensselaer Polytechnic Institute, requested that the treasurer make his report before the motion was considered since the financial condition of the Association had a definite bearing on the questions of publication of a journal and increase of dues. The treasurer, Doctor Klopsteg, then made an informal report and explained that, although there was a considerable surplus in the treasury, this surplus would be used up in a short time and that it would soon be necessary to make the dues sufficient to take care of the expenses of publishing the journal. President Dodge remarked that the large surplus was due to the economical management of the affairs of the Association. Until the Atlantic City meeting all travel expenses of officers and a good part of their office expense has been taken care of without cost to the Association. It has been the policy of the Association to expect all officers, with the possible exception of the Secretary, to provide for their travel either personally or through their institutions. He explained that even under these favorable circumstances it was unlikely that an acceptable journal could be published unless the dues were eventually raised to at least $4.00. Professor Patterson moved an amendment to the effect that the reference to dues of $4.00 after 1933 be deleted. The amendment carried and after some further discussion the original motion as amended was passed unanimously.

The president explained that the acceptance of the opinion of the executive committee that the annual dues should be changed to $3.00 for 1933 was in effect an amendment to the by-laws and would be so regarded.

The report of the nominating committee, as approved by the executive committee, was read for the information of the members. The president explained that a mail ballot would be conducted early in the year.

WILLIAM S. WEBB
Secretary

Annual Report of the Treasurer of the American Association of Physics Teachers

Balance Received from W. S. Webb, January 14, 1931. (Dues of 7 members for 1932 included)		$ 432.51
Dues Collected		
1932, Dues received from 384 members ($3.00 sent in error by one member and an additional 10 cents sent by another to cover cost of exchange)	$769.10	
1933, Dues received from 12 members	24.00	
Total Dues Collected	$793.10	793.10
TOTAL MONEY DEPOSITED		$1225.61

TOTAL MONEY DEPOSITED	$1225.61
TOTAL DISBURSEMENTS	264.83
BALANCE ON HAND, December 31, 1932	$ 960.78

PAUL E. KLOPSTEG, *Treasurer*

December 31, 1932.

We have examined the accounts of the treasurer of the American Association of Physics Teachers for the year beginning January 1st, 1932 and ending December 31st, 1932, and find them to be correct.

HARVEY B. LEMON
GEORGE S. MONK
Auditing Committee

ABSTRACTS

The purpose of these abstracts is to furnish teachers of physics with helpful suggestions from varied sources and with a reliable and comprehensive index of current activities, thought and opinion in the field of physics education. In order to accomplish these aims, it will be necessary to abstract many articles that are controversial in nature or that represent mere expressions of opinion. Every effort will be made to have all aspects of current opinions in science education represented and to present these opinions fairly and accurately. It is therefore not intended that the abstracts shall necessarily represent the editorial views of THE AMERICAN PHYSICS TEACHER. The criteria for the selection of an article to be abstracted should be the actual value of the article to teachers of physics and its publication in a reputable periodical. Critical discussion of any of the material appearing on these pages is invited; such contributions will be considered for publication under the heading, "Discussion and Correspondence."

Apparatus, Demonstrations and Laboratory Practice

1. Small electromagnet. S. R. Williams, W. W. Stifler and T. Soller; *Rev. Sci. Inst.* **3**, 423–426, Aug., 1932. Describes the construction of a small electromagnet which is suitable for student-laboratory. The core is U-shaped and is made of a very soft iron known as "Rema" iron. The pole pieces, of the same kind of iron, fit snugly into holes in the core. The two coils, each consisting of about 2600 turns of No. 12 D.C.C. copper wire, are wound on spools made from sheet brass, and these in turn are mounted on the pole pieces. For an air gap of 1 cm and a magnetizing current of 7 amperes, the field at the center of the gap is about 17,000 gauss. G. A. V.

2. A simple device for demonstrating Brownian movement in gases. D. A. Wells and William Lange; *Rev. Sci. Inst.* **3**, 474–475, Sept., 1932. Describes a method for observing the Brownian movement of smoke particles in air. The apparatus is easily and quickly constructed and requires no adjustments other than focussing an ordinary microscope. D. R.

3. A laboratory apparatus for the determination of the acceleration of a freely falling body. R. M. Bowie; *Sch. Sci. and Math.* **32**, 870–874, Nov., 1932. Describes the construction and operation of an inexpensive, home-made apparatus for determining *g* by a direct method. A 1-in. steel ball is suspended from an electromagnet connected to the 110-volt, 60-cycle line. When a key is opened, the ball is released and simultaneously the current is diverted through a timing device until the ball in its fall strikes and opens a switch. The timing device consists of two styluses which are run by hand over paper soaked in, say, potassium iodide. When the current is flowing out of a stylus, a spot of an iodine compound is deposited on the paper; when the current is in the opposite direction, no deposit is formed. Thus 120 spots per sec. will be formed while the current is flowing and hence the number of spots is a measure of the time of fall. The author states that, in the hands of students, the apparatus gives values of *g* agreeing within 2 percent with the accepted value. D. R.

4. A quantitative test of the conservation of angular momentum. John Mead Adams; *Sch. Sci. and Math.* **32**, 893–895, Nov., 1932. Two equal masses slide freely on a horizontal rod, with a spiral spring connecting them and with an electromagnetically-operated catch to hold them against the tension of the spring when they have been withdrawn to the ends of the rod. The whole system is suspended by two equal parallel vertical wires and thus can oscillate rotationally as a bifilar pendulum. The wires serve also to carry the current which operates the catch. While the system is oscillating, and is just at the middle of its path, the catch is released, the masses spring together, and the corresponding sudden increase in speed is made evident by a marked increase in the amplitude. The author shows theoretically that the constancy of the angular

momentum can be tested by examining the constancy of the product of period and amplitude before and after release; thus the quantities to be observed in the experiment are the periods and amplitudes, before and after release. The conditions of the experiment may be varied by altering the distances of travel of the masses by a movable stop and by starting with a different amplitude. D. R.

5. Note on cathode sputtering. F. H. Newman; *Phil. Mag.* **14**, No. 94, 1047–1049, Dec., 1932. Contains helpful suggestions on the technique of sputtering and the construction of a simple sputtering apparatus. F. W. C.

6. A novel optical screen for classroom demonstrations. Joseph H. Howey; *Rev. Sci. Inst.* **3**, 777–781, Dec., 1932. A new optical screen has been designed for making rays of light visible to large lecture classes. The rays are made to strike obliquely across the screen, making a small angle with the plane of the screen. The behavior of rays of light incident on mirrors, lenses, and prisms can be conveniently demonstrated by using the ordinary forms of these optical devices without any special mountings. On account of the efficient utilization of the available light, this screen makes possible a large size pattern of the paths of the rays so that the pattern can be observed from all parts of a large lecture room. The rays of light are in full view of both the demonstrator and the class at all times. (The author.) F. W. C.

7. An improved boiling-point apparatus. Herbert L. Davis; *J. Chem. Ed.* **10**, 47–49, Jan., 1933. Describes an improved modification of the Cottrell boiling-point apparatus which is suitable for student use as well as for research investigations. The apparatus is free from superheating. It is capable of duplicating the accepted values for the pressure-temperature curve of water from 25° to 100°C. A convenient arrangement is described for the determination of boiling points at any desired pressure such as 760 mm. D. R.

8. A sensitivity-control for the Lindemann electrometer. L. G. Grimmett; *Proc. Phys. Soc.* **45**, 117–119, Jan., 1933. A circuit is given for varying the sensitivity of the Lindemann electrometer by means of one adjustment only. (The author.) F. W. C.

General Physics and Related Fields

9. Trial and error. W. L. Severinghaus; *Sci. Mon.* **35**, 341–347, Oct., 1932. The use and results of the experimental method in science are discussed, with especial reference to those students to whom the results are disappointing in that they do not provide final answers to many questions. Attempts are made to dispel the consequent resentment by giving simple illustrations in which applications of this method led to definite and satisfying results, while raising more general questions to which answers were not immediately forthcoming. The question, "What is light," is then made the basis of discussion, and the present situation regarding its answer is explained. The rôle of the experimental method in the social sciences and religion is discussed by taking illustrations from the past and expressing hopes for the future. G. A. V.

10. Acoustic pick-up for Philadelphia Orchestra broadcasts. J. P. Maxfield; *J. Acous. Soc. Am.* **4**, 122–128, Oct., 1932. This paper describes the acoustic and volume control conditions for the broadcasts of the Philadelphia Orchestra from the Academy of Music in Philadelphia, during the season of 1931–1932. Because of the presence of an audience, acoustic control had to be confined almost entirely to proper placement of the microphone. Tests made with the audience present showed that the reverberation time fell within the band of best auditorium conditions for broadcast pick-up, thus making it possible to place the microphone far enough away from the orchestra to blend the reverberant sound with the direct sound. By means of theory and previous recording experience, the probably best distance of the microphone from the orchestra was then determined; by actual tests of transmission, Mr. Stokowski, the conductor, also chose this distance as the best one. There were interference phenomena along the center line of the hall and the best position relative to this line had to be determined by exploration. A single microphone placed in this final position was found satisfactory for orchestral music alone. When there were soloists also, an additional microphone was placed about fifteen feet in front of the singer and this was "faded in" during the solo parts. Since the microphone was at a considerable distance from the orchestra, a good portion of the energy falling on it was reverberant and hence sudden changes in sound intensity produced a smaller change in total intensity than would be the case were most of the sound direct. Despite this advantage, it was still necessary to employ volume control. In the technique finally adopted, the operator gradually changed the volume transmitted until a value was reached which would be suitable for the crescendo or diminuendo that was approaching. The operator was provided with a score on which were marked the times and amounts of change and hence the volume compression actually was under the control of Mr. Stokowski. In most cases, a change of only 10 to 15 decibels was required, whereas the range of a symphony orchestra is about 60 decibels as measured by the volume indicator. The author states that among the improvements in broadcasting to be sought for in the future are methods for transmitting a full volume range undistorted and for increasing the frequency range. D. R.

11. How changes in the sun's surface are recorded by the earth's magnetism. J. Bartels; *Sci. Mon.* **35**, 492–499, Dec., 1932. The question whether terrestrial magnetic dis-

turbances are related to solar disturbances is discussed by presenting the means, taken in various ways, of magnetic observations since 1835, together with the corresponding sunspot-numbers. For the period 1906–1931, a complete day-to-day record of the world-wide average magnetic activity is presented in a single chart, so arranged as to exhibit the existence of a pronounced 27-day recurrence of active and quiet periods. The identity of this period of recurrence with the period of the sun's rotation, as deduced from recurrences of individually-recognizable sunspot groups, is taken as evidence of some sort of correlation between the two phenomena. Detailed comparison of daily records of magnetic activity and sunspot-numbers fails to reveal any such correlation, either simultaneous or delayed, but yearly averages since 1835 and monthly averages since 1900 are very strikingly alike for the two phenomena, both showing the 11-year sunspot-cycle unmistakably. From these facts the author draws the following conclusions: "Terrestrial-magnetic activity reveals persistent solar influences which are distinctly recognized as such by the 27-day recurrence due to the Sun's rotation. Magnetic activity must, therefore, be attributed to some action of fairly definite regions on the Sun's surface—we call them M-regions. These M-regions can not, at present, be individually identified with any of the phenomena which are directly observed on the Sun. In the averages taken over a number of years, however, the M-regions must vary in area like the sunspots, since magnetic activity shows the 11-year cycle quite distinctly." The hypothesis that the observed terrestrial effects are caused by streams of particles shot out radially from active areas of the sun is discussed briefly. The article concludes with references to a more extended account of the material presented, and to other works bearing on the subject. The author is a research associate in the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. G. A. V.

12. The role of physics and chemistry in biology and medicine. George Crile; *Sch. Sci. and Math.* **33**, 12–25, Jan., 1933. Of interest to teachers of premedical physics. D. R.

13. The constitution of the stars. H. N. Russell; *Science* **77**, 65–79, Jan. 20, 1933. The First Maiben Lecture before the American Association for the Advancement of Science. Doubtless the most authoritative and comprehensive recent summary of the subject available to the non-specialist. D. R.

14. Vibrations produced in bodies by contact with solid carbon dioxide. Mary D. Waller; *Proc. Phys. Soc.* **45**, 101–116, Jan., 1933. The paper describes the conditions under which very loud notes may be produced and maintained for a considerable time in metal objects capable of vibration, such as tuning forks, bars, disks, rings and tubes, when brought into contact with a solid carbon dioxide block. Notes have also been sustained in quartz crystals. It is shown that the vibration frequencies normally excited may range from about 1000 to 15,000 ~. Lower frequencies have been excited in wires. Surface-tension ripples may be produced on mercury. The vibrations are only produced by solid carbon dioxide of high density. The physical properties of the vibrating body which are of importance in connection with the phenomenon are considered. Evidence is brought forward in favor of the view that the source of energy for producing the vibrations is the heat which is given up by the metal to the solid carbon dioxide, and that the efficacy of this substance in producing vibrations is determined by the fact that it sublimes and in so doing produces considerable gas-pressures. Some suggestions regarding possible applications of the phenomenon are made. (The author.) G. A. V.

15. Universe in the red. George W. Gray; *Atlantic Mon.* **151**, 233–239, Feb., 1933. This popular article discusses the now well-known red shift of the light from the extra-galactic nebulae. After presentation of the observed facts, the three explanations of the phenomenon are briefly presented. They are, in order of presentation: Zwicky's gravitational-drag hypothesis, MacMillan's idea that photons lose energy in travelling great distances, and the Lemaître-Eddington theory of the expanding universe. Most attention is given to the last one, and the contributions of Tolman and DeSitter are reviewed. Although written for the lay public, this article could well be recommended to physics students for reading. The author is described by the editors as a journalist whose hobby is scientific research. G. A. V.

Intermediate and Advanced Physics

16. The rapid derivation of thermodynamical relations. A. Norman Shaw; *Trans. Roy. Soc. Canada* **26**, Sect. 3, 187–204, May, 1932. Presents an easy method of procedure for obtaining rapidly any of the derivable relations which involve the first and second partial derivatives of the various thermodynamical variables for a "simple" substance. According to the author, the use of his procedure makes it possible for second or third year university students approaching the subject of thermodynamics for the first time to learn in a few days to derive rapidly, and without confusion, any of these relations. He points out that with the method adopted by current textbooks, more mature students are frequently unable to verify relations which have been already formulated for them.

The method depends primarily on the use of the relation

$$(\partial_x/\partial_y)_z=(A_xB_z-A_zB_x)/(A_yB_z-A_zB_y),$$

where $A_w=(\partial_w/\partial\alpha)_\beta$ and $B_w=(\partial_w/\partial\beta)_\alpha$, in which w represents x, y, or z, any variables which are each functions of α and β. The procedure is explained in detail and elementary examples are included. D. R.

17. Elementary theory of the gyroscope. PETER L. TEA; *J. Frank. Inst.* **214**, 299–325, Sept., 1932. The author states that it is his object "to present the fundamental properties of the gyroscope in an elementary manner, suitable for second-year students of physics." Various experiments are included with the theory. Elementary calculus is employed but the usual simultaneous differential equations are avoided. There are 13 diagrams. D. R.

18. The conception and demonstration of electron waves. C. J. DAVISSON; *Bell Sys. Tech. J.* **11**, 546–562, Oct., 1932. An attempt is made in this article to trace the growth of our ideas regarding the electron from their inception less than a hundred years ago to the present day. The discussion begins with a consideration of the vague and tentative deductions concerning an ultimate electrical charge which became possible when Faraday revealed the laws of electrolytic conduction; it touches upon the clarification of the conception of the electron as a charged particle capable of independent existence and subject to the laws of classical electrodynamics which was effected at the close of the last century and the beginning of the present one by the researches of J. J. Thomson and others; it indicates the difficulties in which this conception became involved, and the attempts made by Planck, Bohr and others to extricate it from them. The latter part of the paper is devoted to the amplified conception of the electron which has been developed during the last decade—a conception in which electrons are recognized as having, in different circumstances, the properties of both waves and particles. (The author.) F. W. C.

19. Contemporary advances in physics, XXIV: high-frequency phenomena in gases, first part. KARL K. DARROW; *Bell Sys. Tech. J.* **11**, 576–607, Oct., 1932. This is an account of the behavior of conducting gases subjected to high-frequency electrostatic fields—behavior which can be interpreted, in many cases with striking success, by supposing that the free electrons wandering in the gas are set into motion by the field, and oscillate and drift according to laws which can be derived from our knowledge of the response of free electrons to steady fields. When a constant magnetic field coexists with the high-frequency forces, the phenomena become more complicated, but remain predictable. There are also peculiar phenomena indicating that the electrons in a conductive gas have certain natural frequencies of oscillation. Applications are made to the absorption of radiofrequency waves in ionized gases. (The author.) H. C. R.

20. A note on Huygens' principle. JOSEPH S. MITCHELL; *Phil. Mag.* **14**, 938–939, Nov., 1932. The theorem of Kirchhoff, generally accepted as a rigorous formulation of Huygens' principle, is derived very briefly by an application of Fourier's integral theorem. D. R.

21. Electric supra-conduction in metals. J. C. MCLENNAN; *Nature* **130**, 879–886, Dec. 10, 1932. A comprehensive summary of the experimental facts with some reference to their theoretical implications. D. R.

22. Contemporary advances in physics, XXV: high-frequency phenomena in gases, second part. KARL K. DARROW; *Bell Sys. Tech. J.* **12**, 91–118, Jan., 1933. This article on high-frequency phenomena in gases, a continuation of the one which appeared in the preceding number of this journal, is concerned with the self-sustaining high-frequency discharges. First come the conditions for establishment of the discharge, a spark or corona if the gas-pressure is high, a glow if it is low; then, the laws of the glow-discharge when established in rarefied gas, in tubes with internal or external electrodes. The complexity of the situation is such that fundamental theory is almost powerless as yet, the article thus consisting chiefly of descriptions of data and statements of empirical laws. (The author.) H. C. R.

23. The Oersted. Director, U. S. Bureau of Standards; *J. Frank. Inst.* **215**, 100, Jan., 1933. The International Electrotechnical Commission has adopted the name *oersted* for the unit of magnetic intensity. The commission has no legal authority but the new use of the term has been accepted by authoritative technical bodies. In the United States, this term has been used for the unit of magnetic reluctance, a fact which makes the acceptance of the new proposal doubtful. However, the U. S. Bureau of Standards has adopted the name *oersted* for the c.g.s. unit of magnetic intensity. The term *gilbert per centimeter*, previously used, still has the same significance and may be used interchangeably with *oersted* if preferred. D. R.

24. A common misapprehension of the theory of induced magnetism. L. R. WILBERFORCE; *Proc. Phys. Soc.* **45**, 82–87, Jan., 1933. It is usually stated that if any given magnet is immersed in a medium of permeability μ the magnetic field around it is similar to that in a vacuum, but diminished in strength in the ratio $1:\mu$. It is here shown that this statement is inconsistent with the ascertained experimental laws of induced magnetism. (The author.) G. A. V.

History and Biography

25. The discovery of the elements. Mary Elvira Weeks; *J. Chem. Ed.* **9**, Jan.–Dec., 1932. A series of eighteen articles which contain useful biographical material and many interesting anecdotes and quotations obtained from original papers and other reliable sources. The illustrations are profuse and of excellent quality. The titles of the articles, with page numbers are: Elements known to the ancient world, 4; Elements known to the alchemists, 11; Some eighteenth-century metals, 22; Three important gases, 215; Chromium, molybdenum, tungsten and uranium, 459; Tellurium and selenium, 474; Columbian, tantalum, and vanadium, 863; The platinum metals, 1017; Potassium, sodium and lithium, 1035; The alkaline earth metals and magnesium and cadmium, 1046; Zirconium, titanium, cerium, and thorium, 1231; beryllium, boron, silicon, and aluminum, 1386; Some spectroscopic studies, 1413; The periodic system of the elements, 1593; Some elements predicted by Mendeléeff, 1605; The rare earth elements, 1751; The halogen family, 1915; The inert gases, 2065. D. R.

Philosophy of Science

26. What consolation in the new physics? Frederick S. Breed; *Sci. Mon.* **35**, 347–351, Oct., 1932. The philosophical doctrines of determinism and indeterminism are discussed. The new physics is invoked only for a statement of its "principle of indeterminacy" (Heisenberg's uncertainty principle), which is used as the starting point for a recanvass of some of the aspects of the age-old conflict between these two doctrines. G. A. V.

27. The origin and destiny of energy. Mason E. Hufford; *Sci. Mon.* **35**, 431–438, Nov., 1932. Brief historical sketches and elementary explanations are given of: (1) the ideas of heat, (2) Carnot's cycle and the second law of thermodynamics, and (3) the "heat death" of the universe. After discussion of the inadequacy of each of the three older hypotheses concerning possible sources of stellar energy—namely those postulating combustion, meteoric fall, and contraction—a more detailed review of modern ideas on this and related subjects is given. The viewpoint adopted is that of one to whom the idea of the heat death is distasteful, and who seeks to deny the general validity of the second law of thermodynamics. Along these lines the modern ideas of stellar energies as arising out of either annihilation of matter or the building of helium out of hydrogen are presented, together with Millikan's ideas on cosmic rays and the possible upbuilding of the elements in interstellar space. The growth of the common basis of all these, the working hypothesis of the identity of matter and energy, is traced from its beginnings in Maxwell's theory, through relativity. The finite universe is discussed, but not the expanding one. The conclusion reached is that modern trends seem to point toward a reversible cycle for the energy transformations of the closed universe, permitting an escape from the heat death for the universe as a whole. G. A. V.

Comments by the abstractor: Although they in no essential respect impair this lucid presentation of an interesting topic, some inadvertences seem to have crept into this article. The implication (top of p. 433) that the possibility of perpetual motion is precluded by the second law of thermodynamics reverses the usual logical order, in which one bases the second law on the non-existence of perpetual motion of the second kind. Also, the values for the mass of an electron obtained from the Kaufmann Bucherer experiments (assuming e constant) are not proportional to the velocity (as stated on p. 437), but increase with velocity by the factor $1/(1-v^2/c^2)^{\frac{1}{2}}$. G. A. V.

Physics Teaching and Science Education

28. Cultural aspects of engineering education. K. T. Compton; *J. Eng. Ed.* **23**, 69–76, Oct., 1932. The author concludes that "we should make more clear-cut the distinction between technical and engineering education; that we should uphold the importance and dignity of the technical schools and advise some so-called engineering schools frankly to recognize their nature and real opportunity as technical schools; that our criteria for real engineering schools should include the best possible basic training in the sciences and fundamental engineering subjects, with some specialization and with very considerable attention to the place and problems of the engineer in society; and finally that we should recognize that there is a vital cultural element in engineering, whose recognition by engineer should lead to their increased confidence and satisfaction in their work and whose recognition by the public should lead to the increased prestige and recognition which the importance of their work justifies." D. R.

29. A critical summary of the research on the lecture-demonstration *versus* the individual-laboratory method of teaching high-school chemistry. Dewey B. Stuit and Max D. Engelhart; *Sci. Ed.* **16**, 380–391, Oct., 1932. The authors conclude that the evidence is conflicting and that the problem is yet unsolved. D. R.

30. Sound motion pictures as an aid in classroom teaching. CLARENCE C. CLARK; *Sch. Rev.* **40**, 669–681, Nov., 1932. As the result of a carefully conducted study made with junior-college students, it is concluded that sound films, silent films, and lecture-demonstration showed no marked superiority, one over the other, in science teaching. D. R.

31. How much arithmetic and algebra do students of first year college physics really know? WILLIAM R. LUECK; *Sch. Sci. and Math.* **32**, 998–1005, Dec., 1932. The *Compass Survey Test in Arithmetic, Advanced Examination* and the *Douglass Diagnostic Test in Elementary Algebra, Series B, Form II*, were given to 280 students of first year college physics in five Iowa colleges. In arithmetic, these students exhibited approximately seventh-grade ability. In algebra the mean number of problems solved was 47 percent, whereas high-school students who are just completing their first year of algebra solve on the average 62 percent; only 27 percent of the students exceeded the high-school norm. About half of the students had pursued or were taking courses in college mathematics; it was found that this college training has a decided influence on achievement in algebra whereas its effect on arithmetical ability is less marked. The author lists the operations in which many errors occurred. He found, for example, that the percentage of error in operations involving decimals only, or fractions only is rather low, but when either decimals and fractions, fractions and percentage, or decimals and percentage are combined in a problem, the percentage of error is high. Nearly half of the students were unable to change a certain percentage to a decimal. In algebra, it was found that there are many operations that present great difficulty to students of first-year college physics. The greatest difficulty is presented by radicals, roots and exponents, the percentage of error being 53. Fifty-six percent of the 4490 disabilities in algebra consisted either of problems omitted or of impossible and meaningless solutions. The author concludes that his data leave no doubt as to the validity of complaints of teachers that students of first-year college physics exhibit serious mathematical weakness. D. R.

32. College dominance in secondary-school science. ELLIOT R. DOWNING; *J. Higher Ed.* **4**, 22–23, Jan., 1933. Secondary schools need to reorganize their science instruction to inform a consumer of science, not to train a producer of science. University science is for the most part producer science and when university graduates go out to teach in colleges and high schools, they teach what they have been taught and as they have been taught. Their students go on to the universities for advanced training, get still more research science, and then in turn go out to teach and perpetuate the process. "It is a vicious circle. It can be broken only as wise principals and superintendents draw their science teachers from those teacher-training institutions that impart consumer science and train in appropriate methods of instruction." By their entrance requirements the universities dominate the character of secondary-school science. For example, entering students must show evidence that their science was done in secondary school by the laboratory method. "Numerous experimental studies have shown that the demonstration method under present conditions is about as efficient except in the matter of developing manipulatory techniques which are not important in consumer research." "Smaller high schools that are now debarred from university affiliations because they cannot incur the expense of science laboratories could equip for instruction with excellent demonstration facilities." "It is a hopeful sign that many leading universities are dropping some specific entrance requirements and are devising means of selecting students on a basis that more nearly insures their ability to accomplish effectively work of university grade. It is furthermore significant that many universities are organizing the college with its aims of general culture apart from the university that functions to train research men." The author is associate professor of science teaching in the University of Chicago. D. R.

GENERAL EDUCATION

33. Comparisons of short-answer and multiple-choice tests covering identical subject content. A. W. HURD; *J. Ed. Research* **26**, 28–30, Sept., 1932. A short-answer test and a multiple-choice test were given in 36 schools after 15 days of instruction on a teaching unit for which the tests were prepared. The multiple-choice test proved to be the easier test. It was also the less reliable, probably because students are less careful in answering, on account of its apparent ease. Apparently the two types of tests do not measure exactly the same functions. It is concluded that the short-answer test is probably the most satisfactory as an objective test. D. R.

34. Luck and examination grades. CHESLEY POSEY; *J. Eng. Ed.* **23**, 292–296, Dec., 1932. No matter how much care is exercised by the teacher in selecting representative examination questions and in stating them so as to insure that all the students will have an equal chance, the element of luck will impose a limit to the accuracy of the examination as a measure of the student's knowledge of the subject matter. This is because the teacher cannot ask all that he expects the students to know, but must confine himself to a comparatively few questions. Mathematical computation of the probabilities that a student whose actual knowledge of a subject is 50 percent, 70 percent or 90 percent will get various grades on 10, 20 or 100-question examinations show a large gain in accuracy in increasing the number of questions to 100. By a "question" is meant the smallest

unit to which a grade is given. For example, of a thousand students who should fail because they have learned only 50 percent of what they should have learned, 72 will pass a 10-question examination, 57 will pass a 20-question examination, and practically all will fail a 100-question examination. The probable error in the grade is greater for the poorer students, which bears out observation that if a poor student is allowed to repeat an examination often enough he will finally be lucky enough to make a passing grade. The author points out the questionable nature of the assumptions that it was necessary to make in order to be able to compute the probabilities mathematically but states that the results "give an idea of the magnitude of the variation to be expected, and provide an argument against the fraction of a percent grading system that some teachers use." D. R.

35. New-type or objective tests: a summary of recent investigations. J. Murray Lee and Percival M. Symonds; *J. Ed. Psych.* **24**, 21–38, Jan., 1933. The recent literature on objective tests is summarized under the following headings: teaching value of new-type tests; comparative validities; comparative reliabilities; scoring methods; special problems peculiar to the true-false test; students' attitudes toward testing; new types of tests. The paper also contains an extensive list of references. D. R.

36. The research racket. Philip W. L. Cox; *Clearing House* **7**, 260–265, Jan., 1933. The following quotations may serve to define the tenor of this article. "*First of all we should recognize that education itself is not and cannot be a science.* It uses the findings of several sciences and it utilizes technics which are roughly analogous to those of science." "It should be evident, therefore, that despite all of the technical hocus-pocus of research there really is no way of correcting data which is not originally reliable and representative. Neither can conclusions drawn from research have a constructive meaning unless the assumptions which underlie the study are valid. These two facts invalidate much, perhaps most, so-called educational research." The author is professor of education at New York University. D. R.

Miscellaneous

37. Developments and trends in mechanical engineering. Editorial staff; *Mech. Eng.* **54**, 845–858, Dec., 1932. A review of mechanical technology and professional development in 1932. D. R.